Organismos edáficos y comunidades vegetales: determinantes ambientales de su distribución ante el cambio climático

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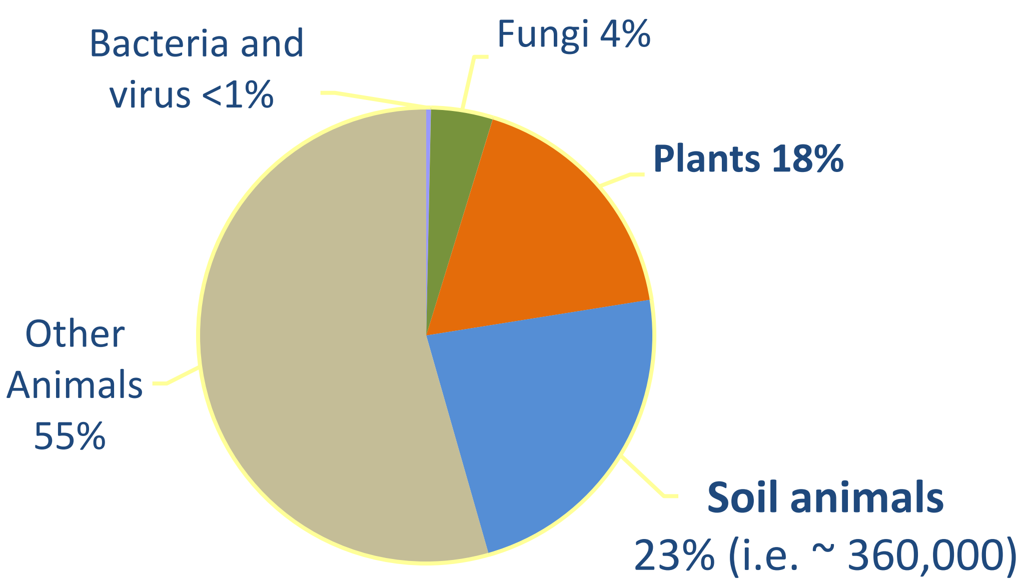
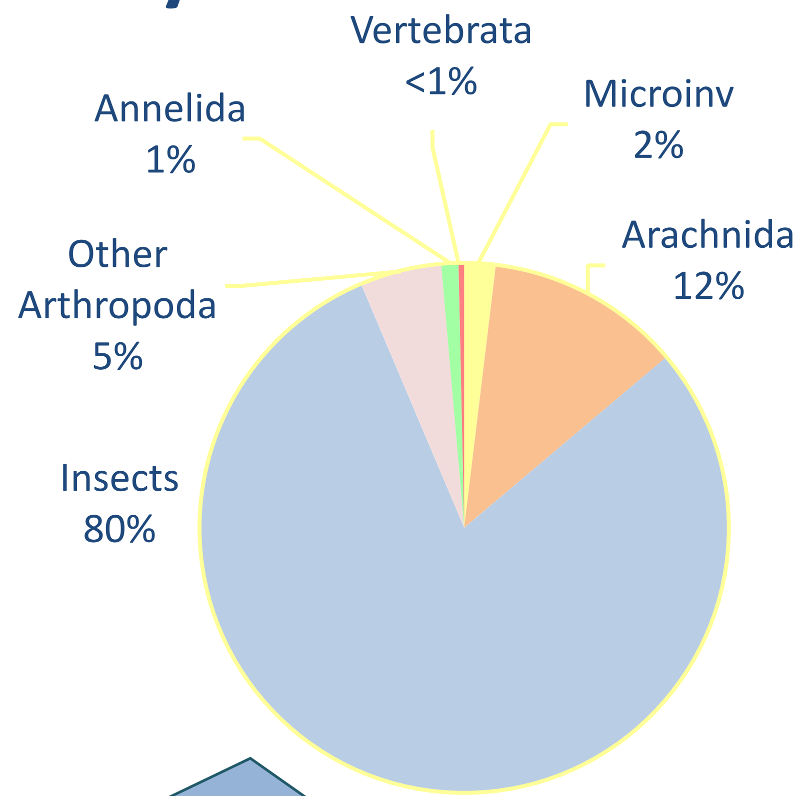
XX Cursillo sobre Flora y Vegetación en el Pirineo

Jaca, 22 de Julio de 2015

Global diversity



Total number of described living species: ~ 1.5×10^{6}



- Importance of soil fauna for global biodiversity
- Taxonomic composition of the global soil fauna

After: Wall, web sites

The enigma of soil biodiversity, or why so many species?

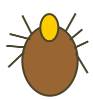
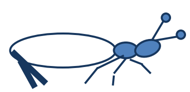
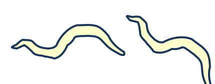
Soils are commonly utmost biodiverse

- ≅ 25% of 1.5×10^{6} described species
- Five -fold the diversity of forest canopy

Handful of forest soil harbours

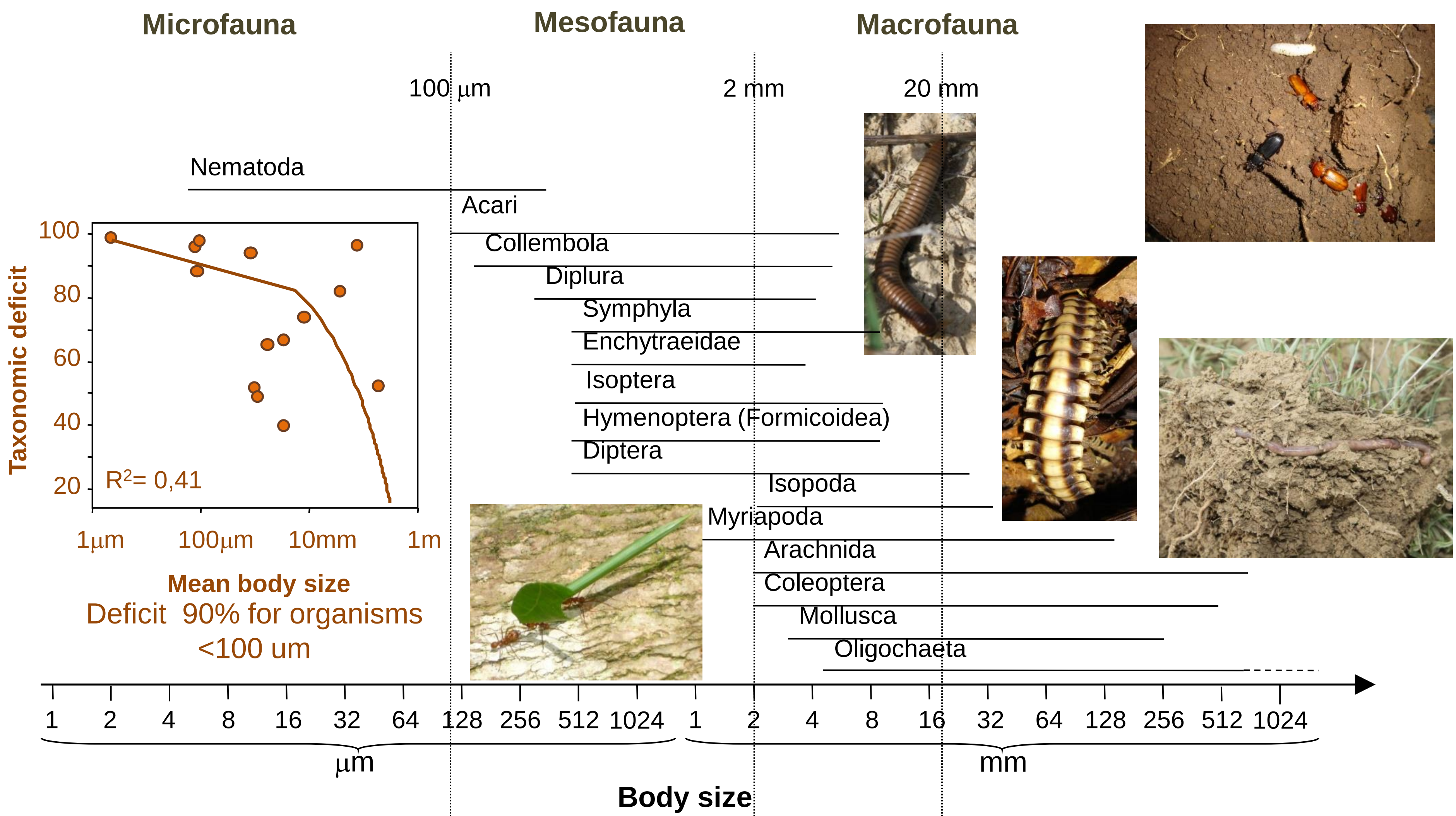
- Hundreds/thousands of species of soil meso-fauna and tens of macrofauna (Schaefer & Schauermann 1990)
- 4,000 genotypes bacteria and 2,000 species of fungi in 1 g soil (Torsvik et al. 1994; Hawksworth 2001)

Soil organisms are packed extremely dense

- 300,000 mites m^{-2} 
- 100,000 collembola m^{-2} 
- 2×10^{6} nematodes m^{-2} 

Soils: the third biotic frontier

Main taxonomic groups of soil organisms on a body-size basis



Pictures © J.J. Jiménez

(After Swift et al. 1979; Decaëns 2010)

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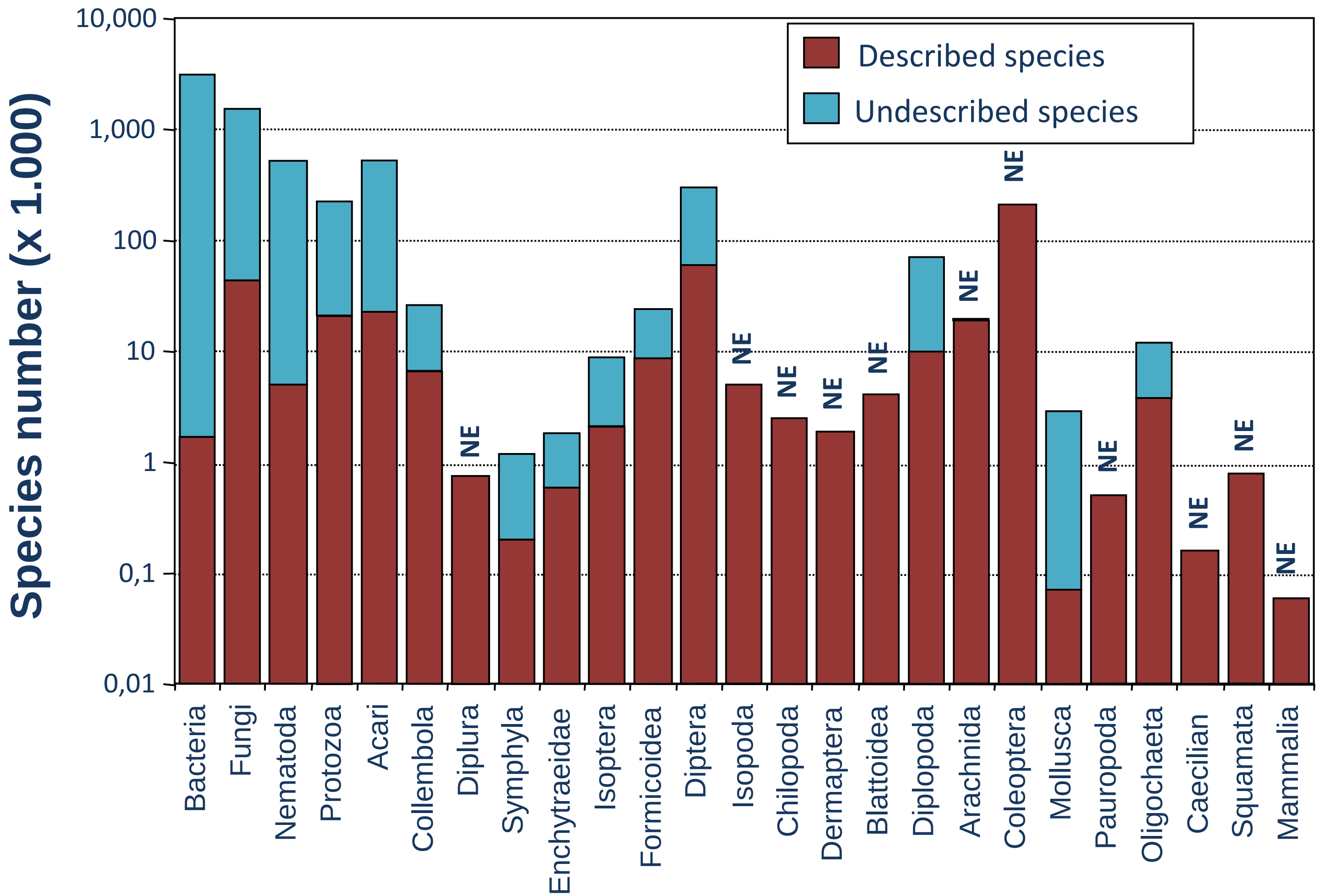
Soil organisms (Known and estimated figures)



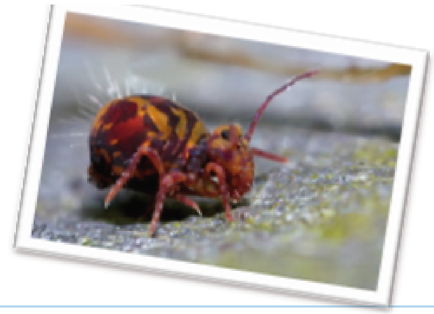
Body size

- How many soil invertebrate species exist worldwide?
- Right now there is no soil where we are able to identify or even quantify all the resident invertebrate species.

www.prairieecosystems.pbworks.com/Dennis-NaturalistGuide

Global number of described species and estimated number of existing species of the main taxonomic groups of soil organisms (after Decaëns, Jiménez et al. 2006)

Soil biodiversity: the final frontier

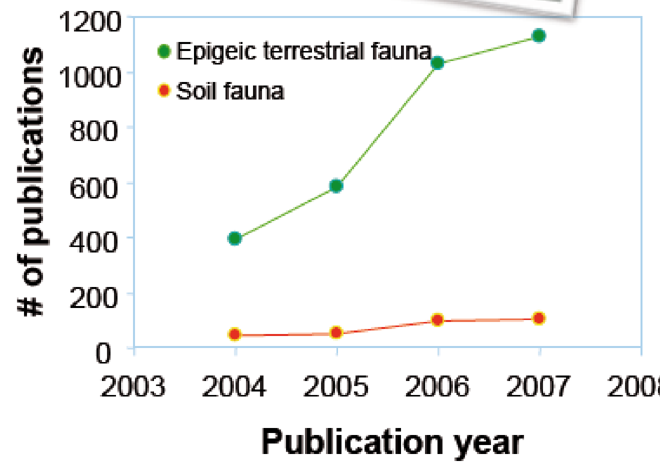


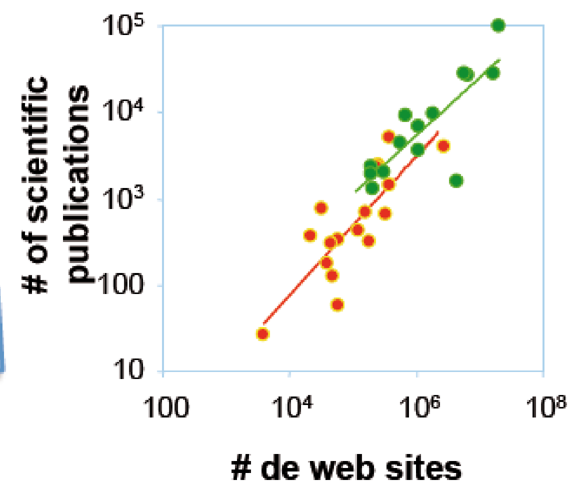
- **Taxonomic impediment**

➢ **Little consideration in biodiversity literature:**
  - Low representation in scientific literature
  - Low interest from the great public

➢ **Overlooked diversity**

➢ **Limitation for soil ecology**
  - Biogeography, macroecology, community to population ecology
  - Ecotoxicology
  - Bioindicator development, etc…





Deficit of taxonomists

Legacy issue

90% for organisms <100 µm

Giller (1996), Brussaard (1997), Behan-Pelletier (1999), André (2001), Wall, André (2002), Decaëns (2010)

DNA barcoding

THE ROYAL SOCIETY

Received 29 July 2002
Accepted 30 September 2002
Published online 8 January 2003

Biological identifications through DNA barcodes

Paul D. N. Hebert*, Alina Cywinska, Shelley L. Ball and Jeremy R. deWaard

DNA Barcoding = the use of a short standardized gene fragment for species identification and biodiversity exploration

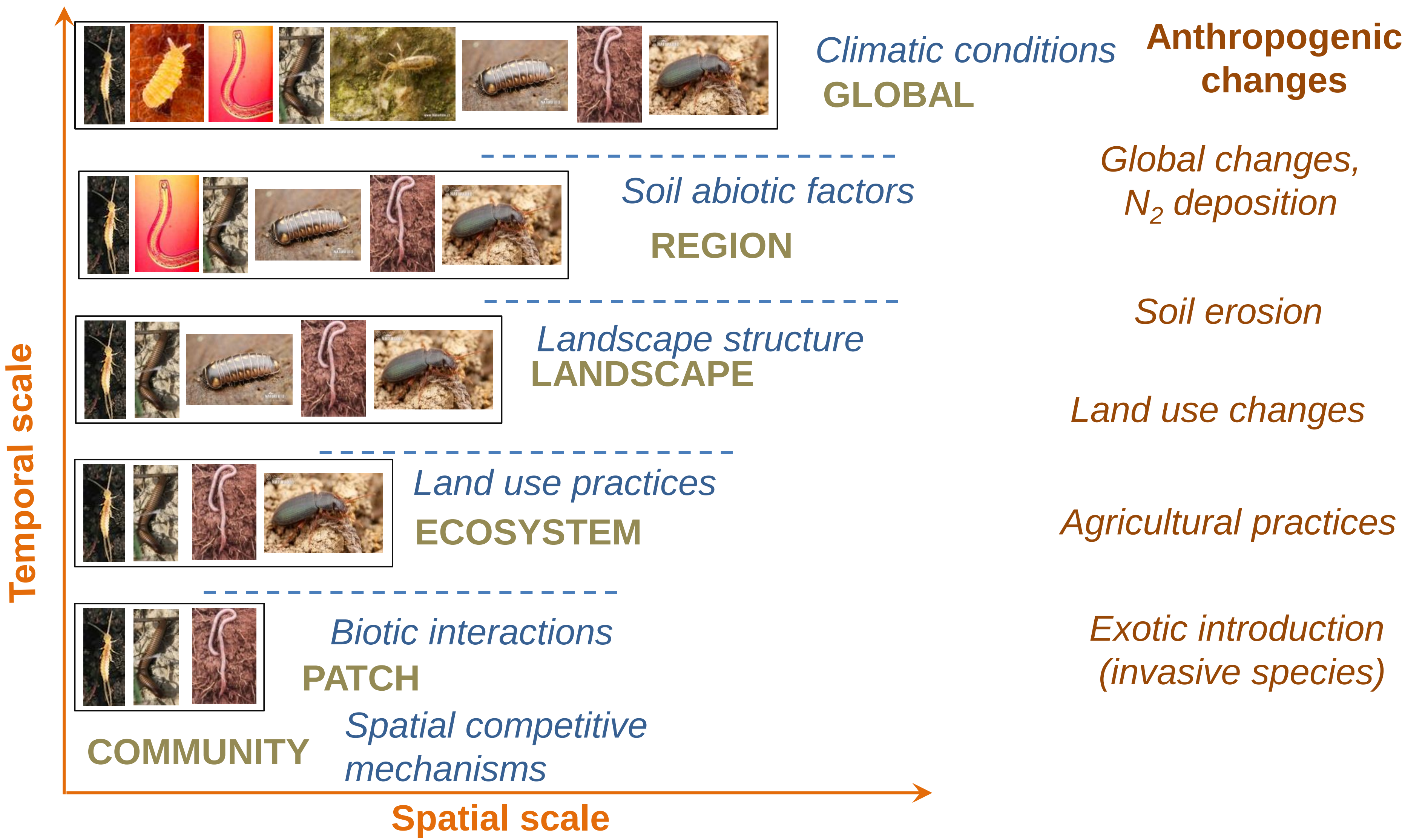
Cytochrome c oxidase I (COI) is the selected standard 'barcode' in animals

→ ***A standardized identification method for animals***

!!! an unsuspected number of cryptic species not distinguished on a morphological basis.

(Herbert, 2003)

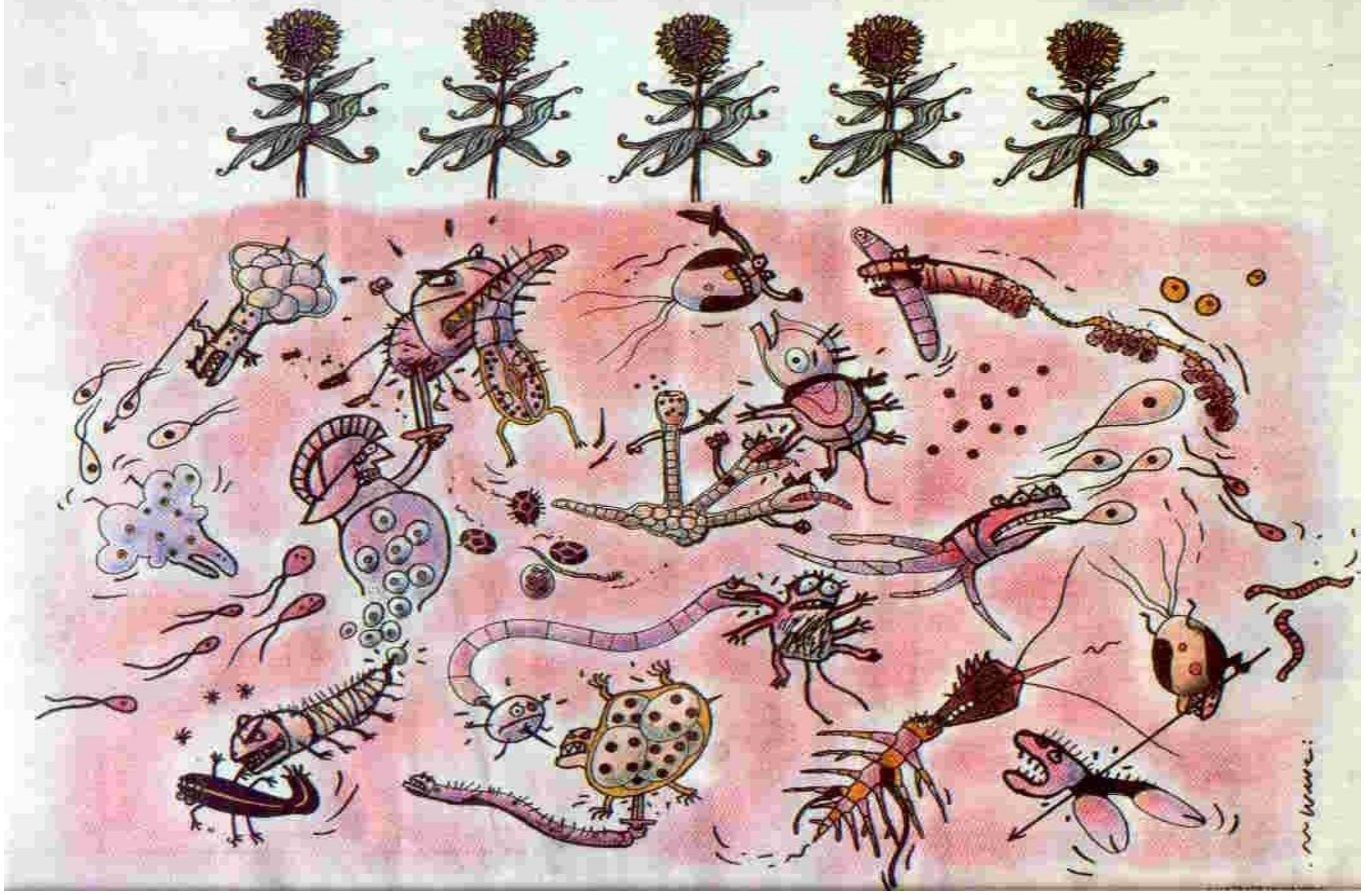
Species pool hypothesis

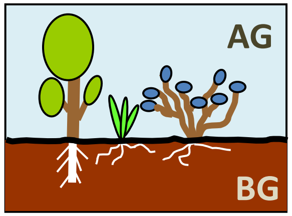


Pictures © Pavel Krasensky; J.J. Jiménez; Tree of life web

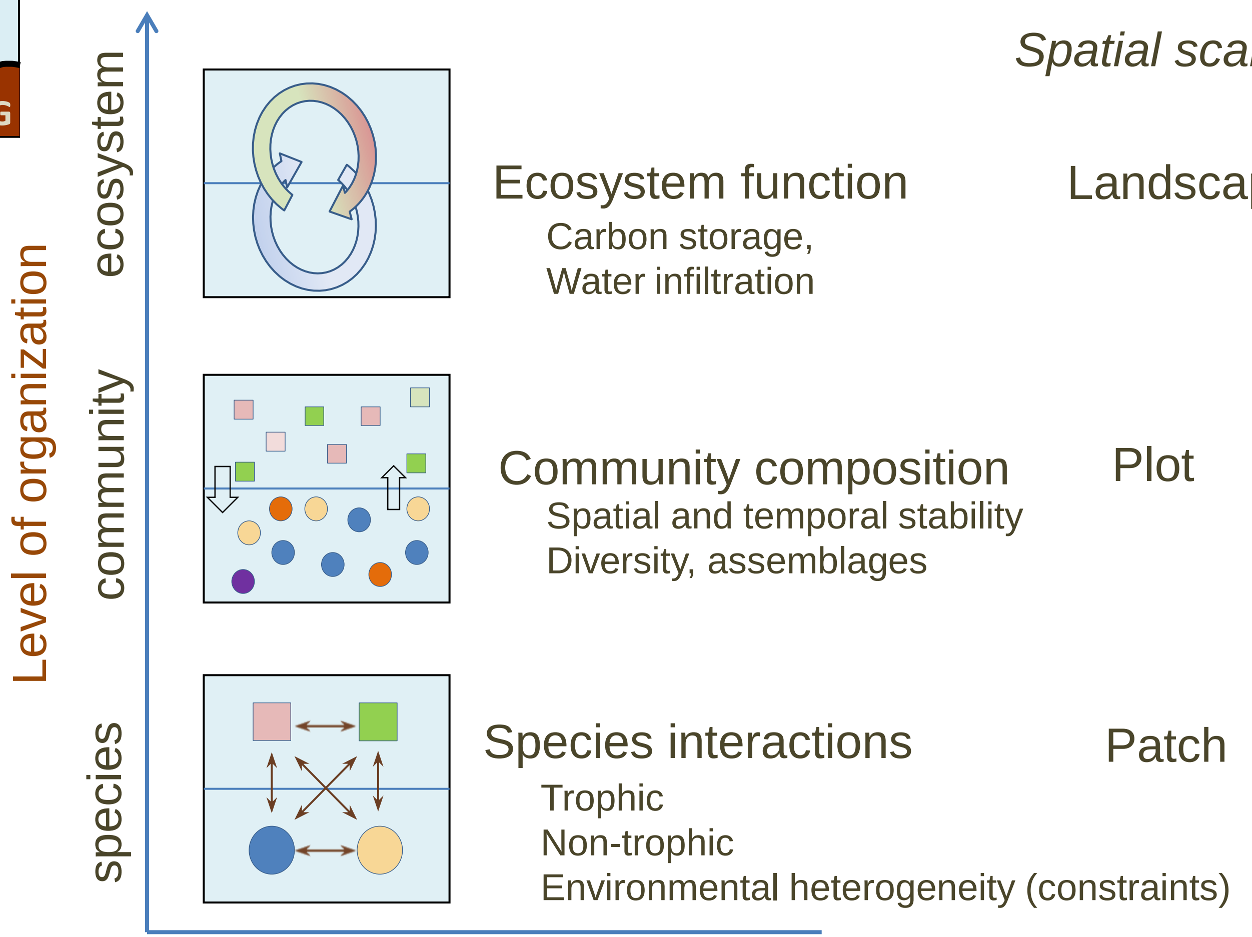
(Decaëns, Jiménez et al. 2006)

Modelos e hipótesis que explican la gran diversidad de organismos del suelo y sus relaciones?





Above- and belowground interactions

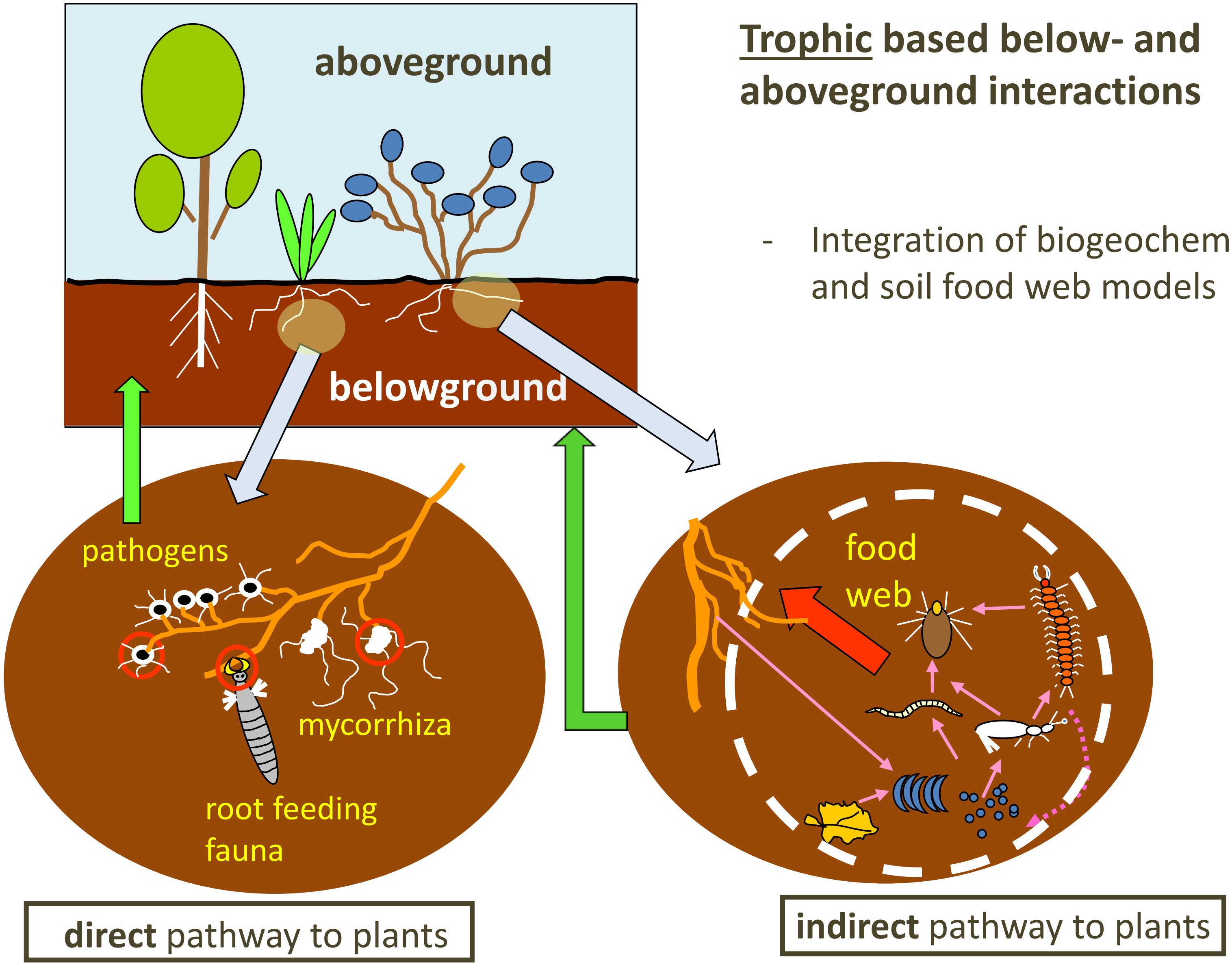


Level of organization = criterion level (Allen and Hoekstra 1990)

(after Kardol and Wardle 2010)

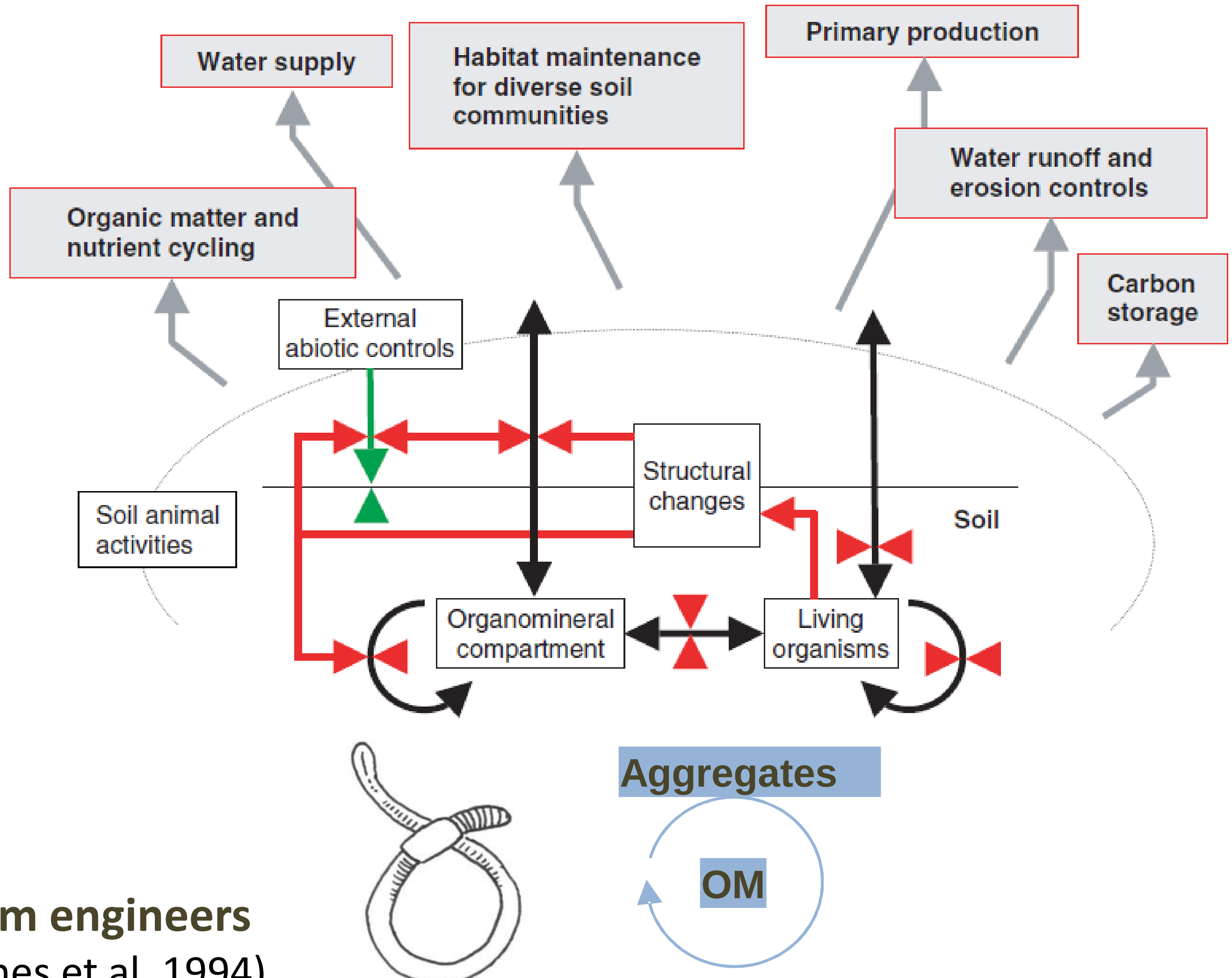
Trophic based below- and aboveground interactions

- Integration of biogeochemical and soil food web models



(Wardle et al. 2004; Osler and Sommerkorn 2007)

Soil ecosystem engineering – **Non-trophic based** interactions



Ecosystem engineers
(*sensu* Jones et al. 1994)

(Decaëns et al. 2008)

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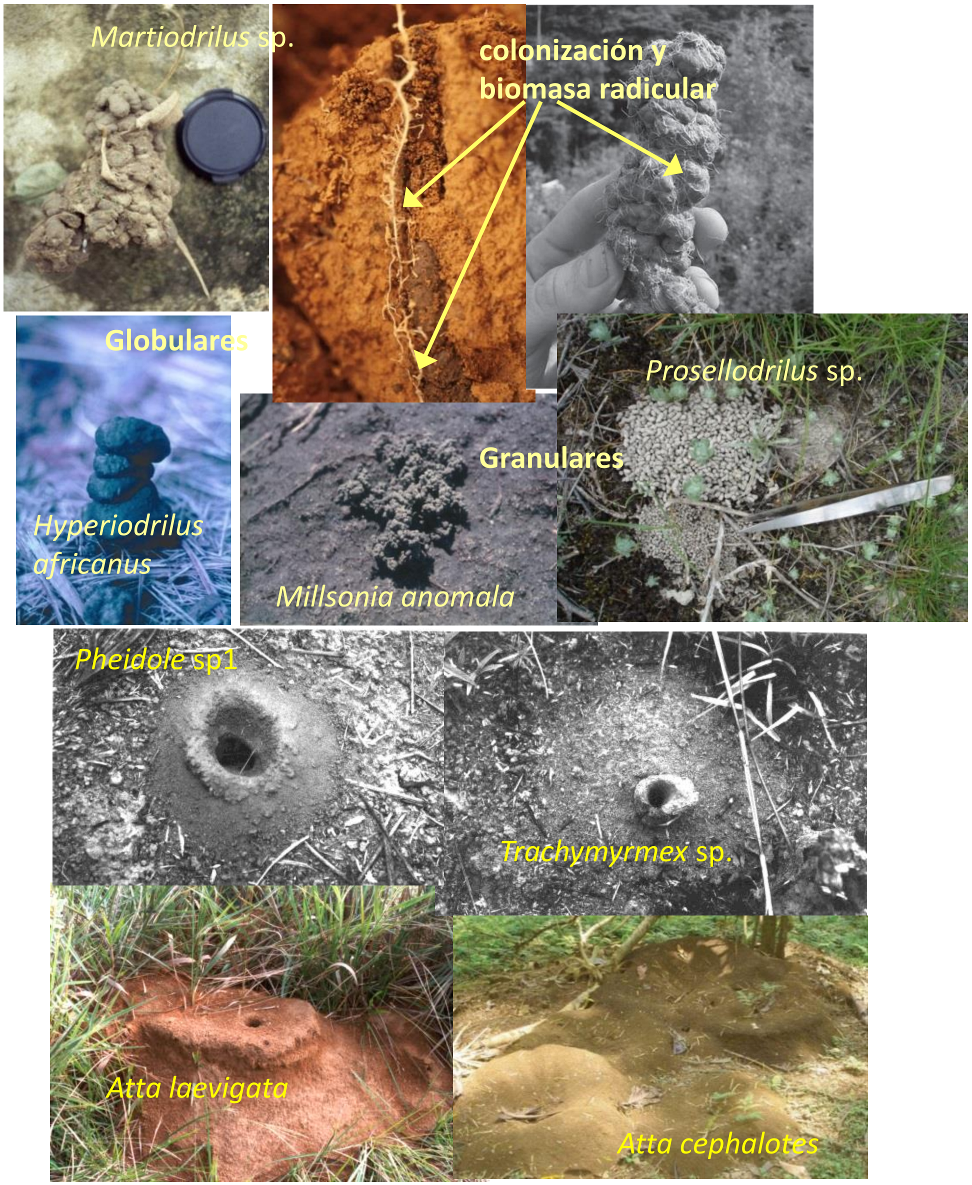
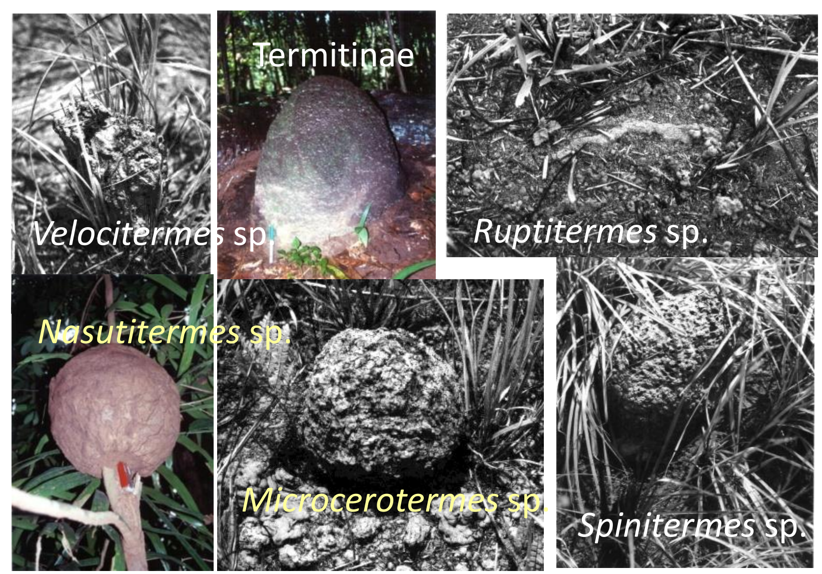
Major drawbacks: Ecosystem engineering is overlooked



Soil habitat transformation

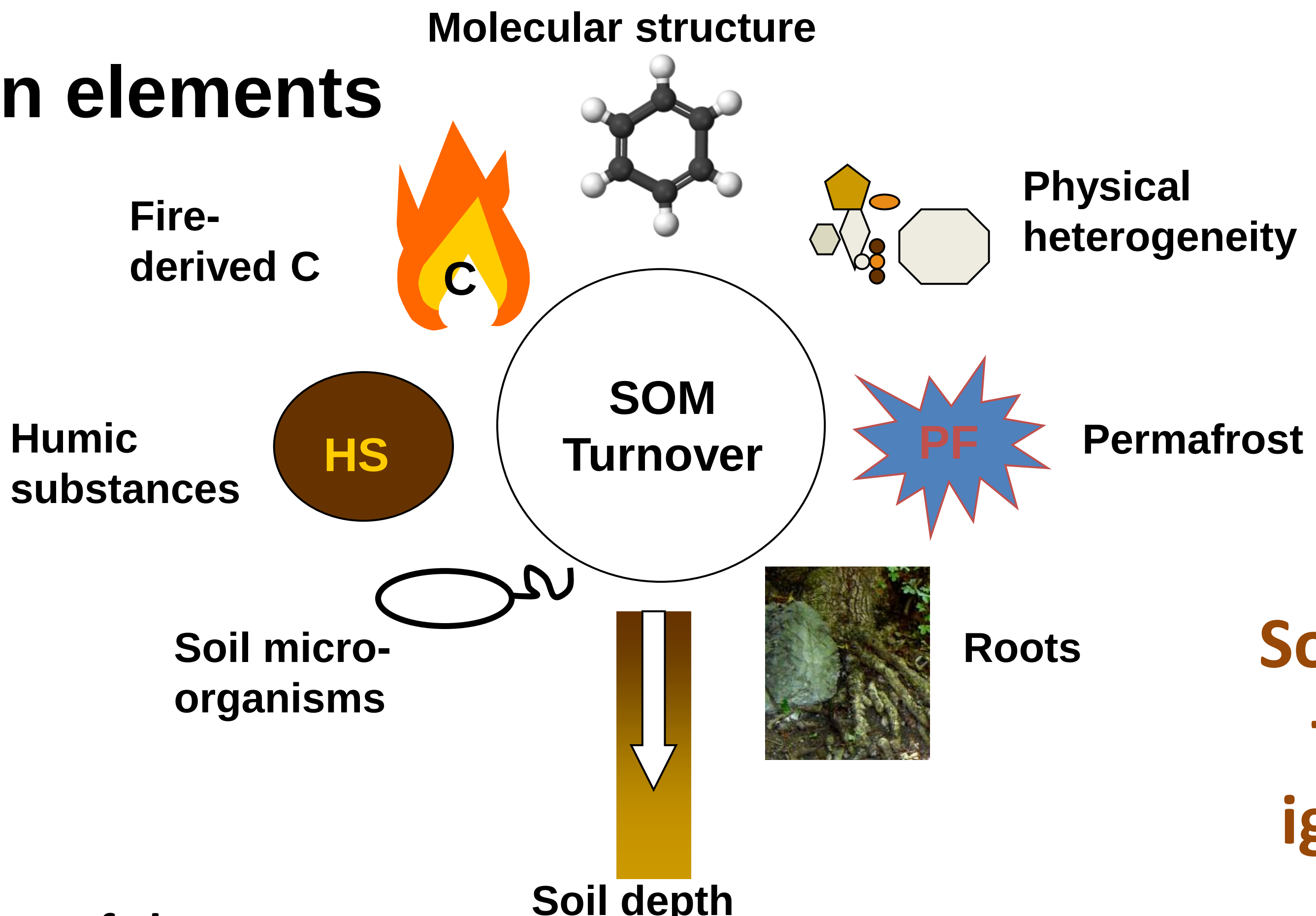
Indirect modification of resources *via* production of physical structures

- In soil: earthworms, ants, termites, and roots



Existing Models on SOM Turnover – relevance for Climate Change predictions

Main elements



Soil fauna totally ignored!

State-of-the-art
(Schmidt et al. 2011)

COST is supported by the EU Framework Programme Horizon 2020

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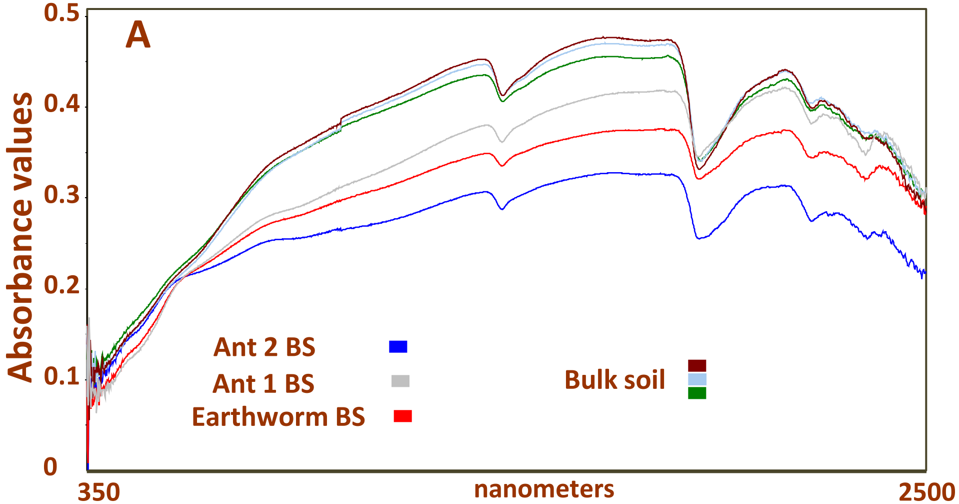
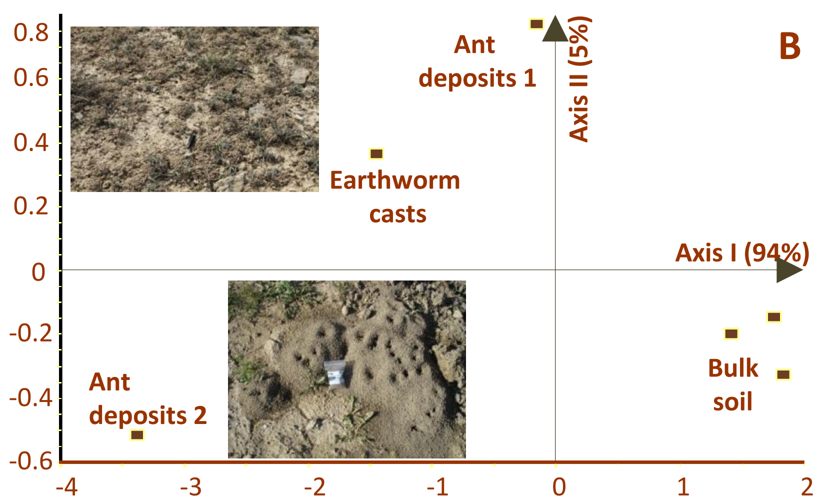
Visible and Near Infrared Spectroscopy (NIRS) signatures of biogenic structures

VNIR spectra





Specific organic fingerprints in biostructures

Functional diversity of soil ecological engineers

Soil as a mosaic of functional domains

(Jiménez et al., sin publicar)

Study site

Surroundings of Ordesa and Monte Perdido National Park, UNESCO Heritage and LTER network site.

Climate alpine, 5 ºC and 1,720 mm

Alpine grasslands grazed by domestic cattle during summer.

July-August 2014;

Earthworm species:

Aporrectodea rosea Savigny 1826

Lumbricus friendi Cognetti, 1904

Prosellodrilus pyrenaicus (Cognetti, 1904)

Study site

Smooth grazing gradient

Stocking pressure	High	Intermediate	Low
Plant richness	Medium	High	Low
Plant community	Rumicion	Bromion	Nardion
Dominant plant species	*Chenopodium bonus-henricus, Trifolium repens, Poa supina*	*Festuca rubra, Agrostis capillaris, Trifolium pratense, Lotus corniculatus*	*Nardus stricta*

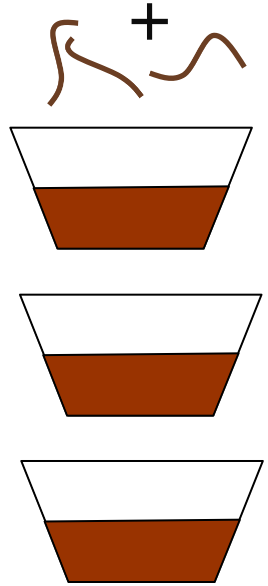
(Bueno and Jiménez, 2014)

Bromion erecti

Nardion strictae

Lab protocol

<2 mm sieved soil



3 reps /
3 species

EW removal 1d

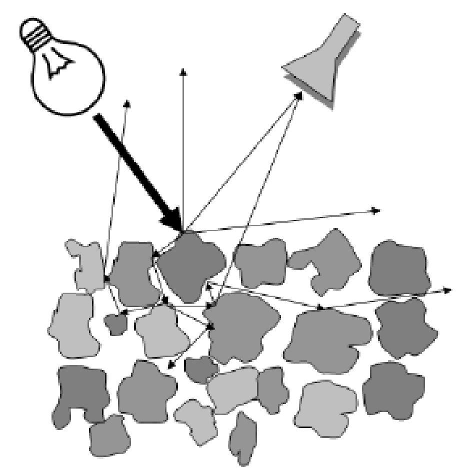
Soil and ew casts
Incubation
1 – 32 (64) days

casts
retrieval

sieved at <200 µm

NIR spectral
readings

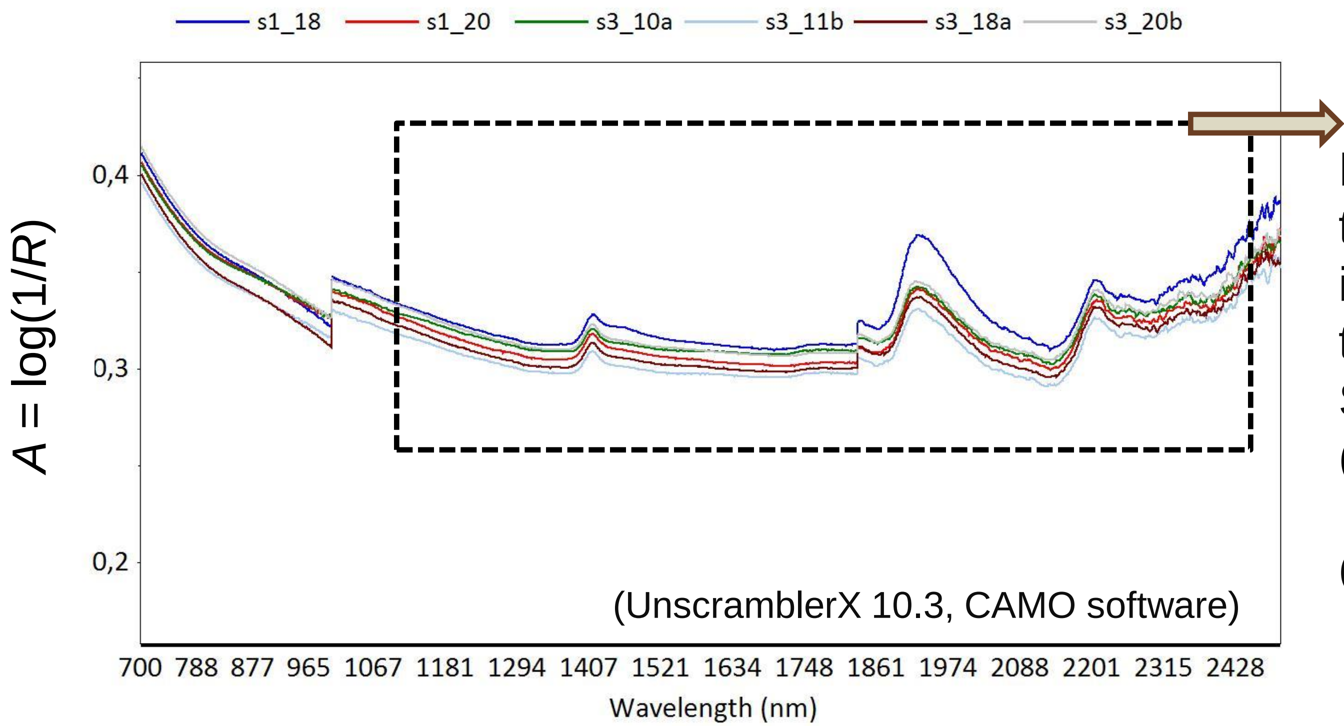
QualitySpec®
spectrophotometer



Diffuse reflectance
(Stenberg et al. 2010)

C and N determinations with dry combustion method (Variomax CN Analyzer, Germany)

Data analysis



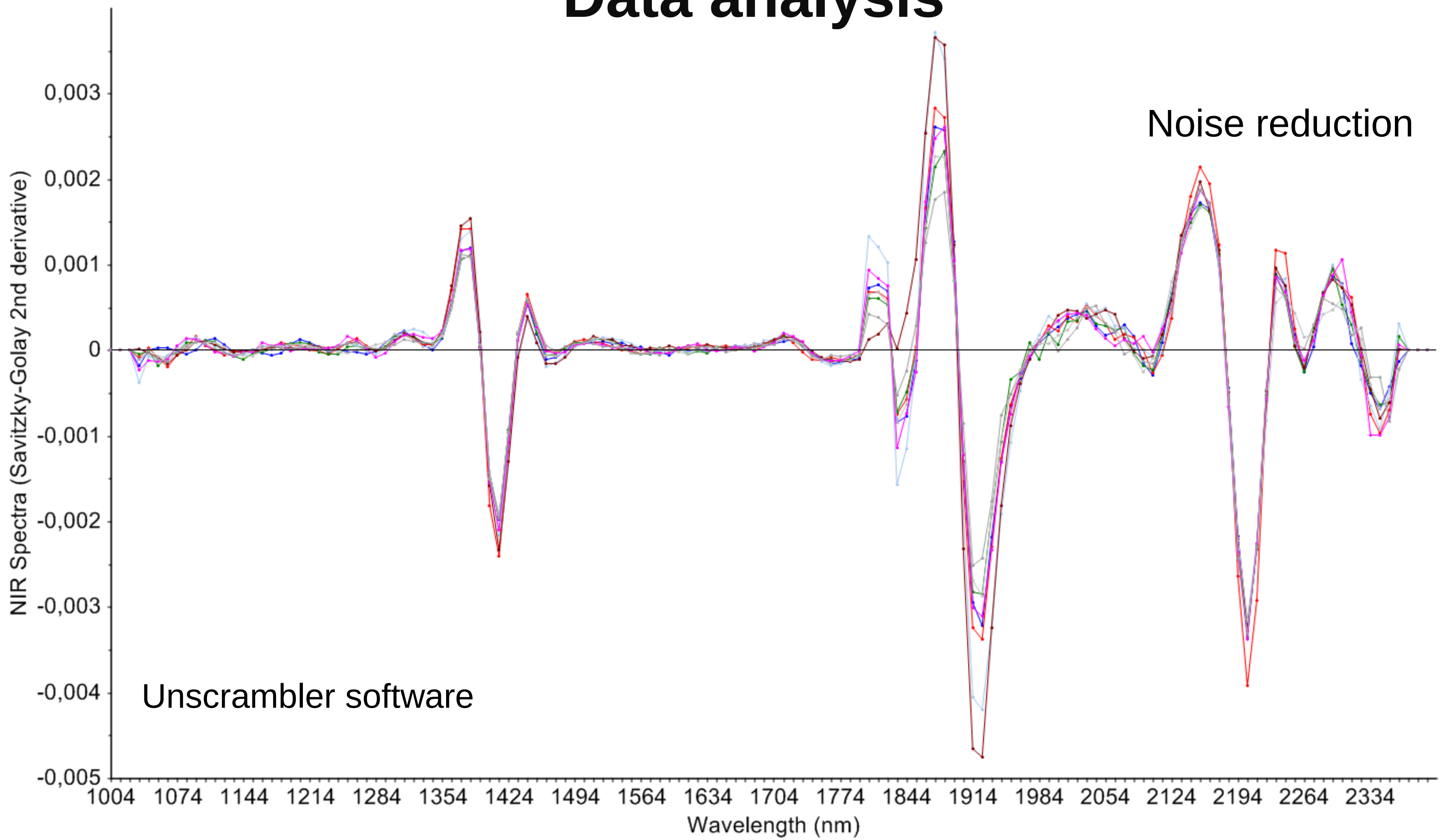
NIR spectra from 1100 to 2300 nm (10 nm intervals) further transformed to Savitzky-Golay 2nd deriv (noise reduction).

(Savitzky and Golay 1964)

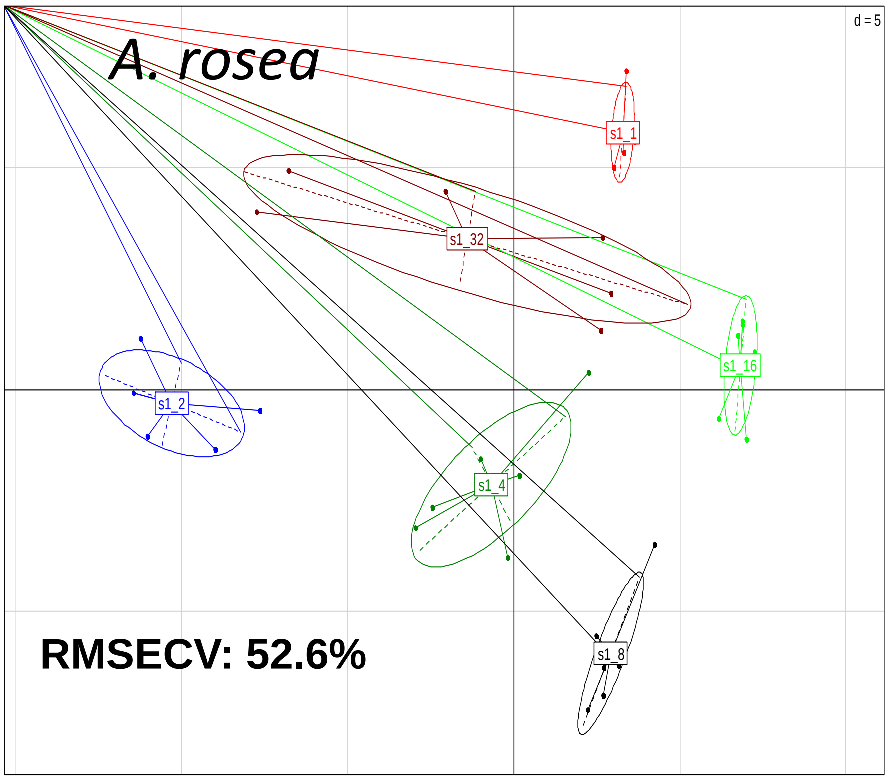
Reflectance (*R*) is converted to absorbance (*A*)

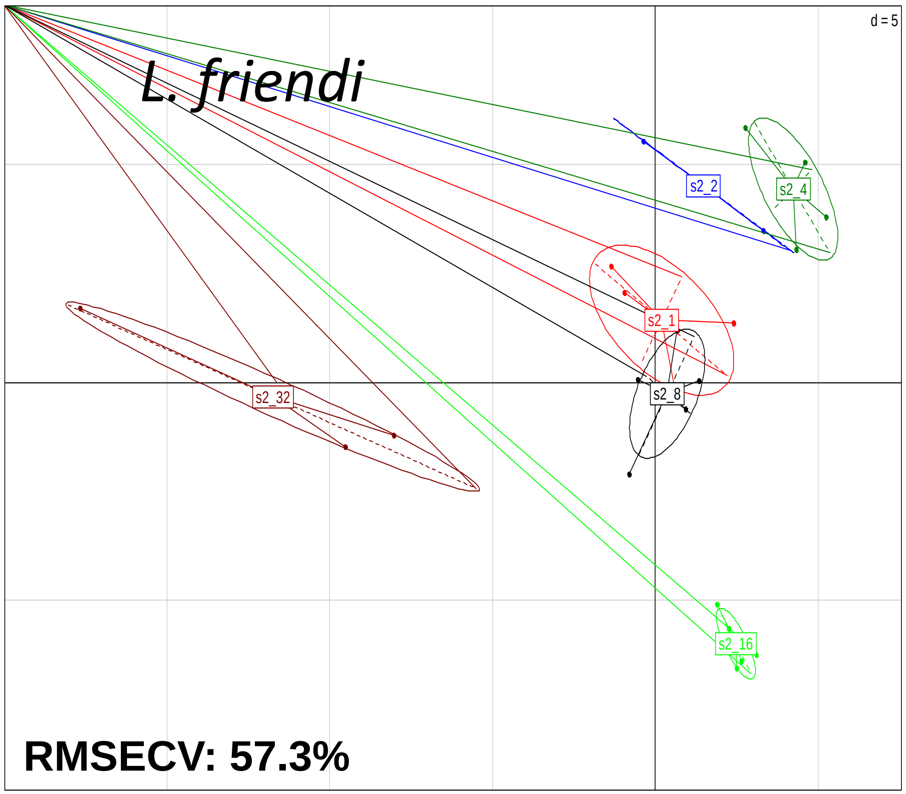
PCAs and Partial Least Square Regression and NIRS library use

Data analysis

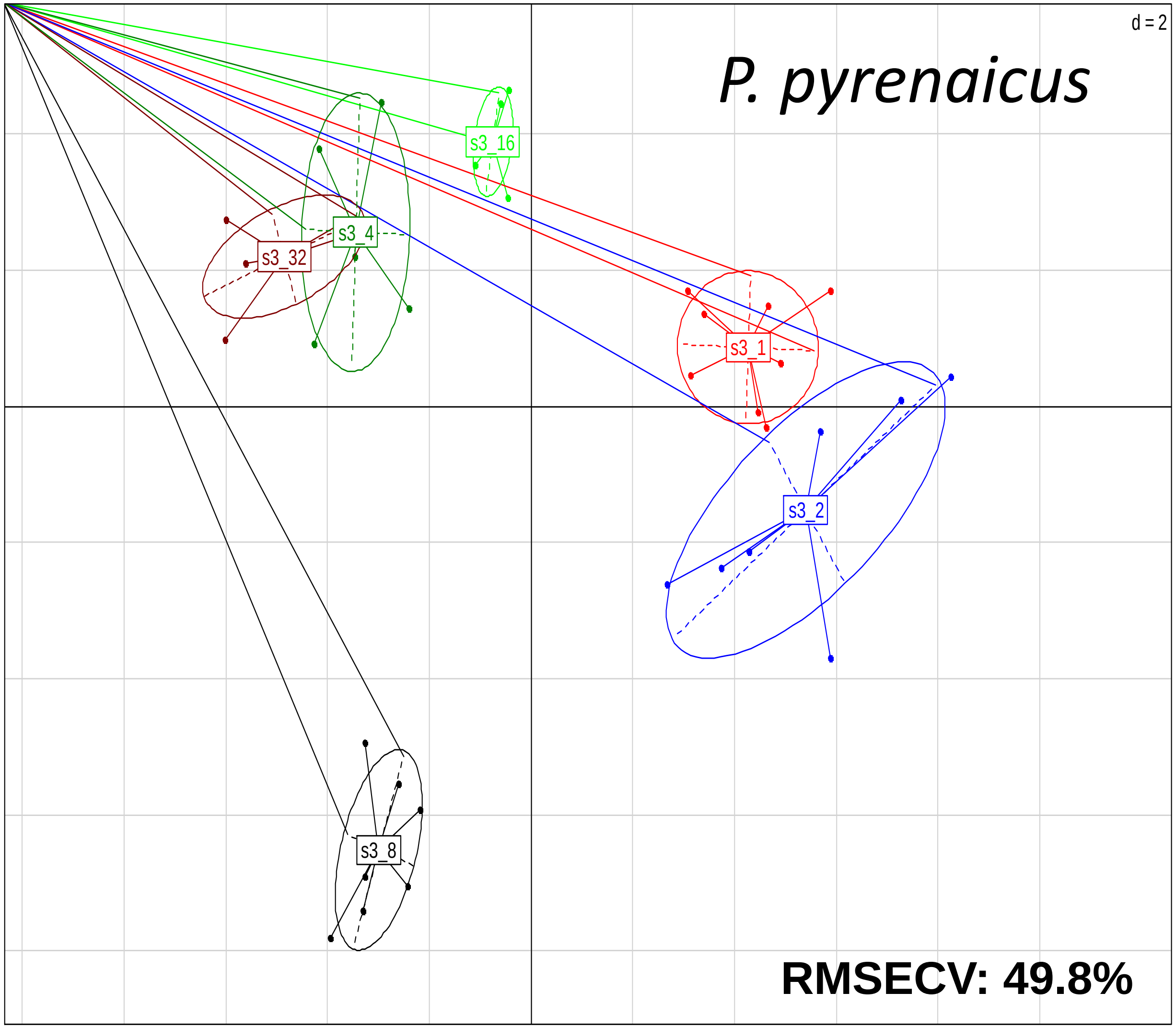


NIR spectra of ageing casts

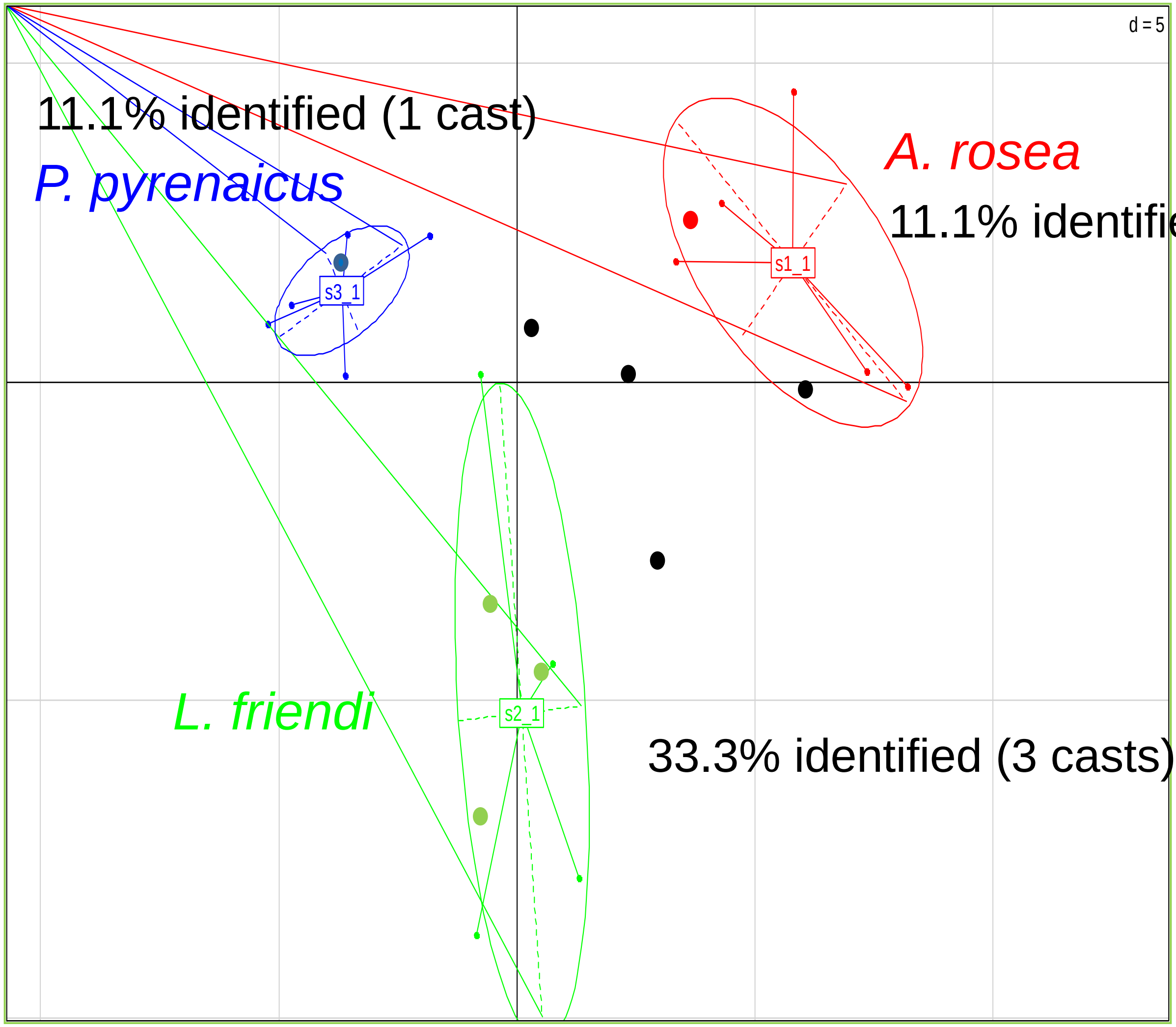




NIR spectra of ageing casts



Projection of field signals



Not identified:
44.4% (4 casts) !!

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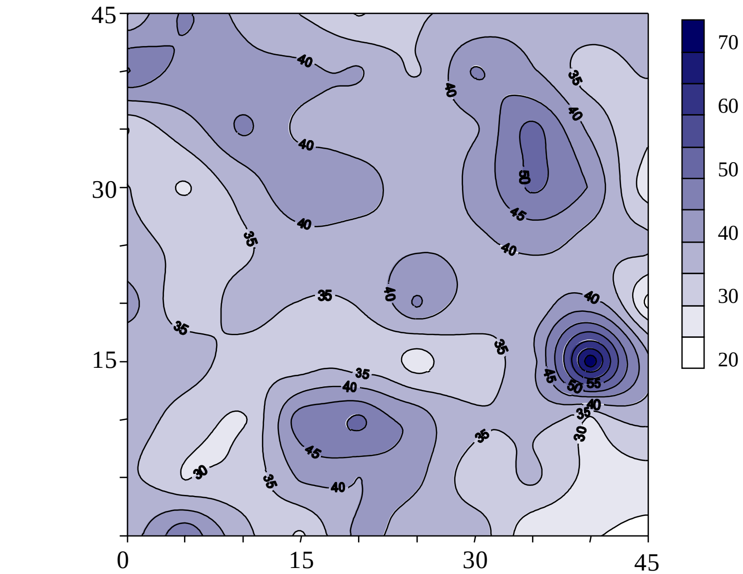
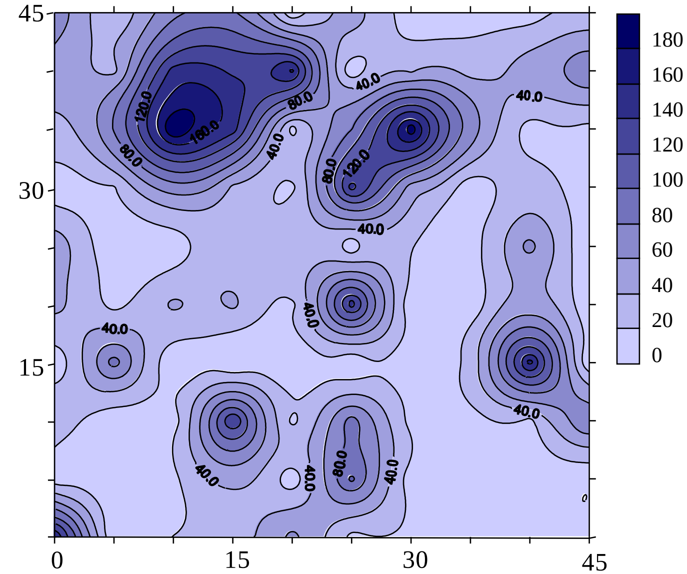
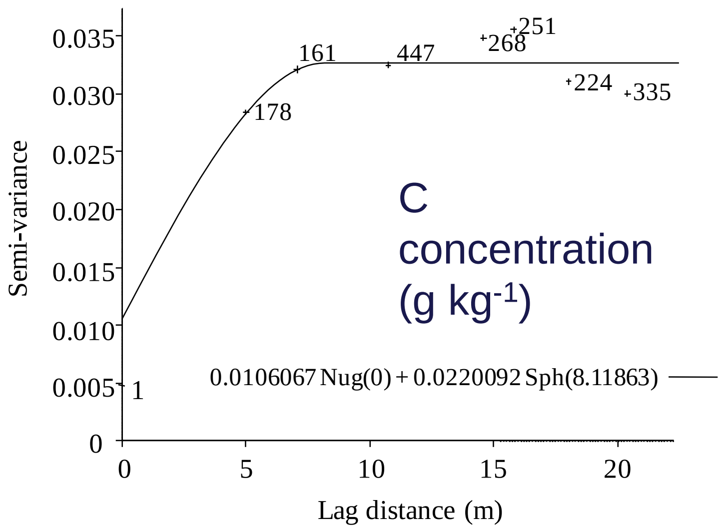
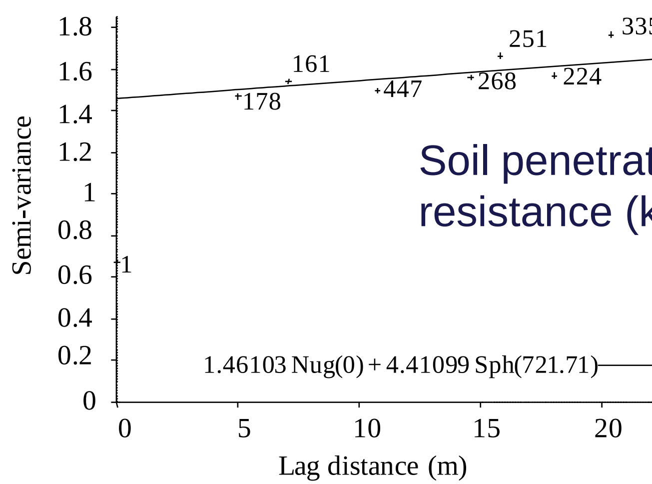
Spatial distribution of selected soil variables







C concentration (g kg^{-1})



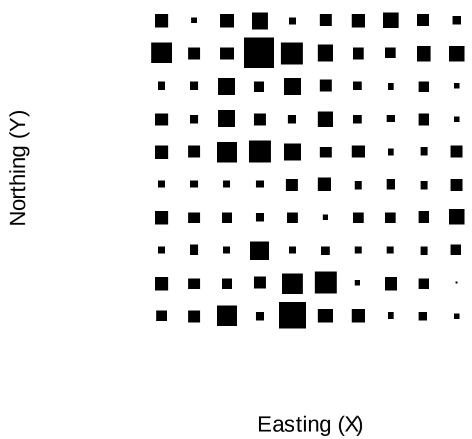
Soil penetration resistance (kg cm^{-3})

(Jiménez et al. 2011)

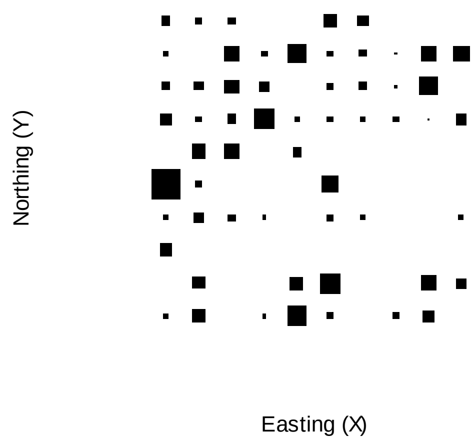
Spatial distribution of resources and organisms

Vegetation – soil invertebrate interactions

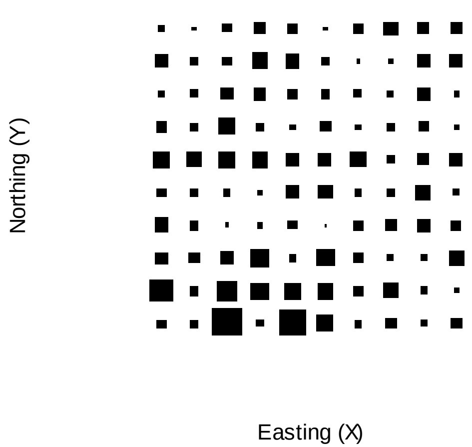
Fine roots Length (m)



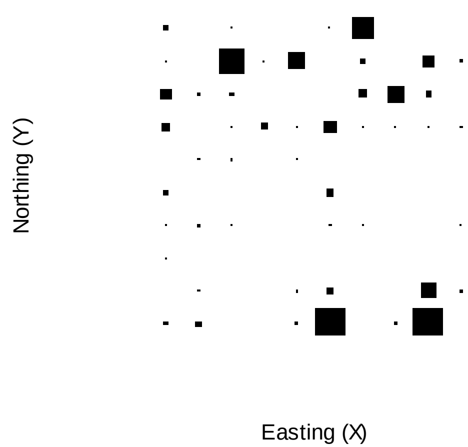
Coarse roots Length (m)



Fine roots Weight (kg)



Coarse roots Weight (kg)



Regular grid of 10x10 points

Soil sampling (Metal cylinders):

- ⊗1 Size-class aggregates
- ⊗2 Root length and biomass (fine and coarse)
- ⊗3 C, N and P determinations
- ⊗4 Bulk density, hydraulic conductivity and soil compaction

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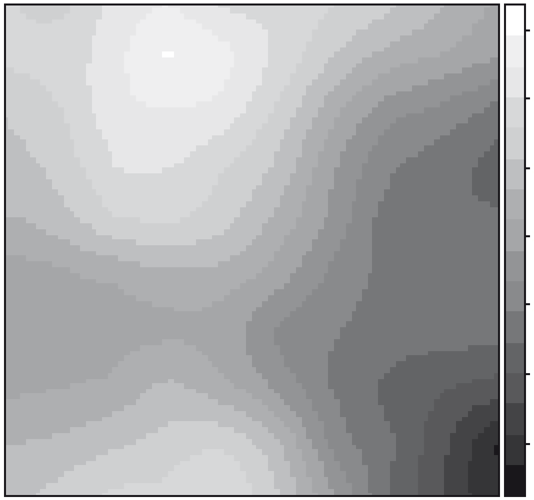
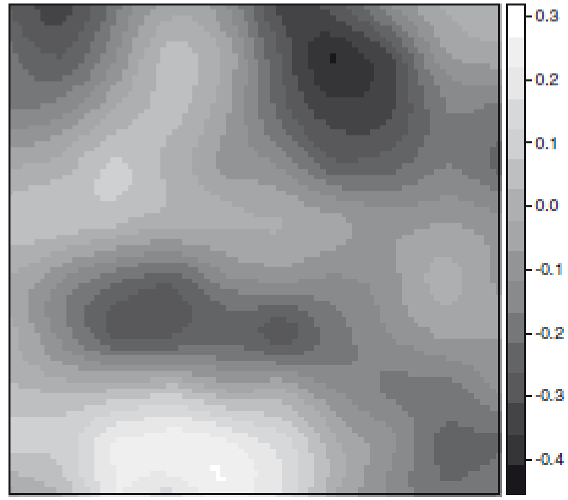
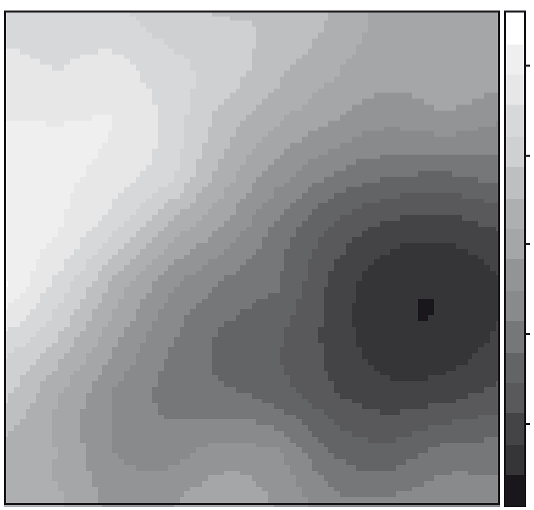
Spatial distribution of resources (fine and coarse roots)



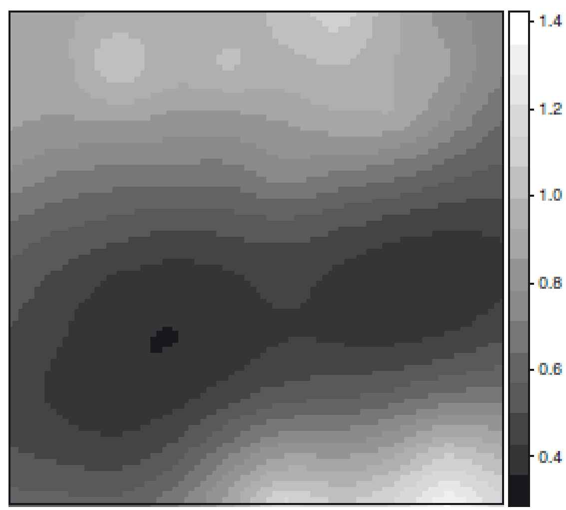
a) Fine root length (m sample^{-1})



b) Fine root weight (g dry wt sample^{-1})



c) Coarse root length



d) Coarse root weight

Cross-correlogram for roots and soil nutrient- and physical-related variables:

FiRL with SOC and P

CoRL with N, SOC and P

FiRW with SOC and P and litter

CoRW with SOC, P

FiRL with Aggregates, Cond and Moisture

CoRL with Aggregates and Cond

FiRW with Aggregates and BD

CoRW with Aggregates

(Jiménez et al. 2014)

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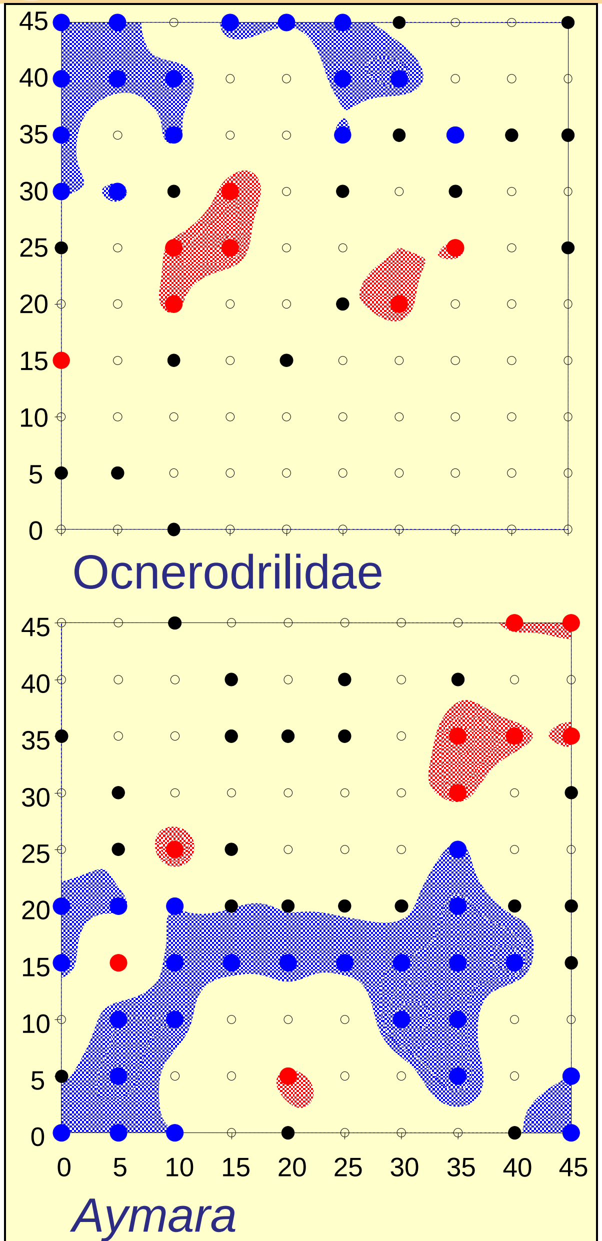
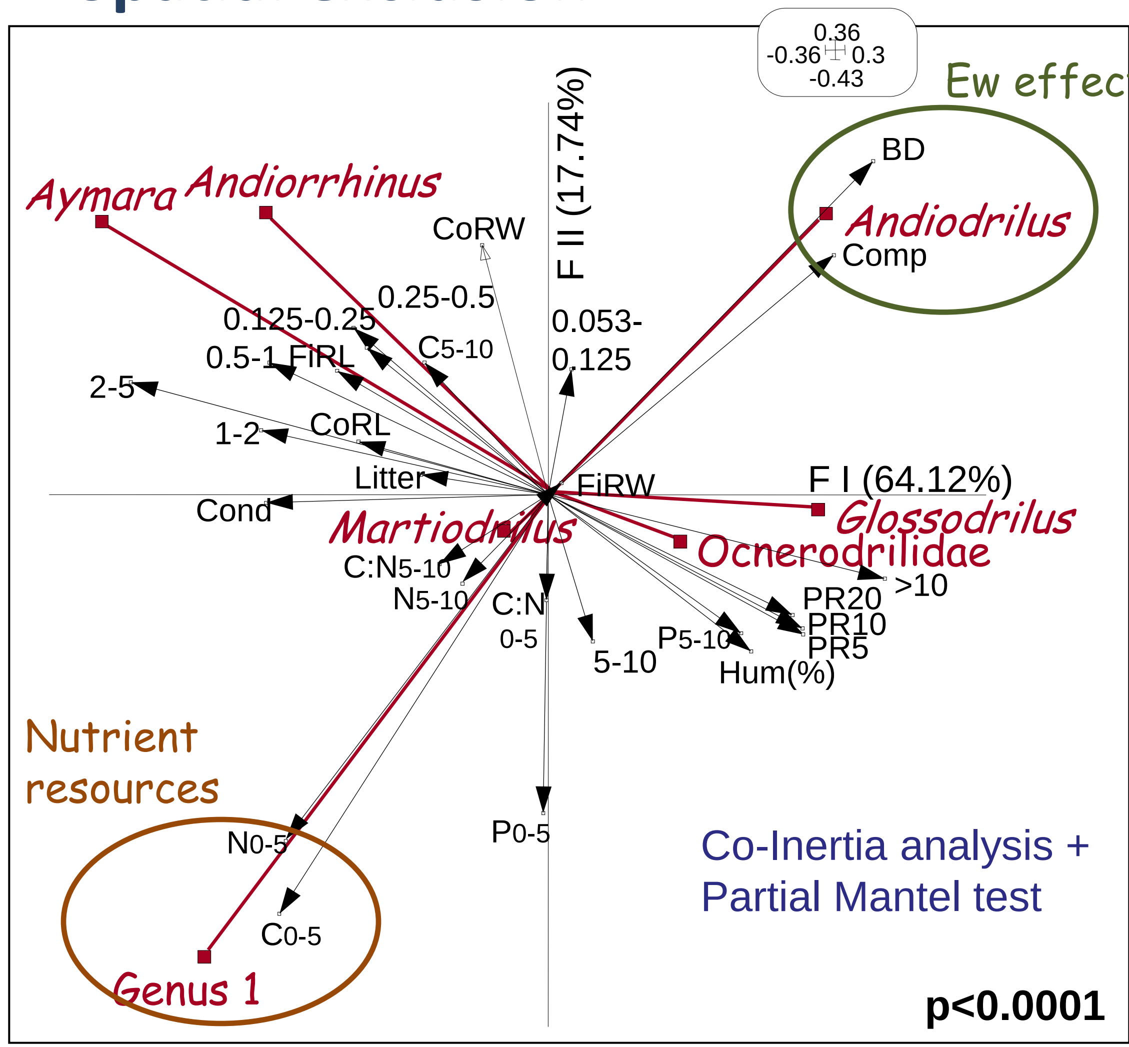
Spatial exclusion



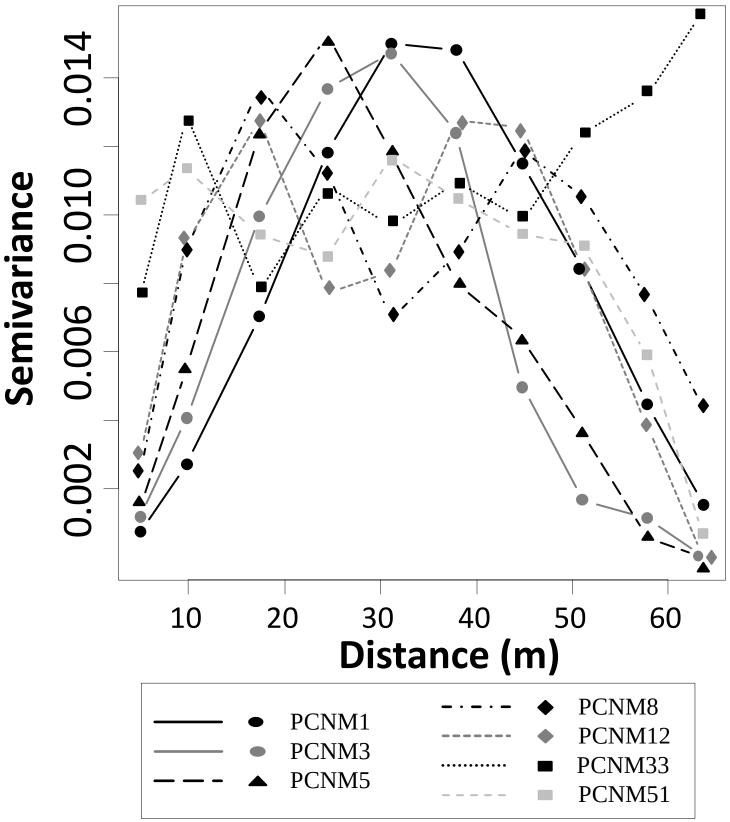


Overlaid contour and classed post maps (surfer) of SADIE clustering indices for counts of two species

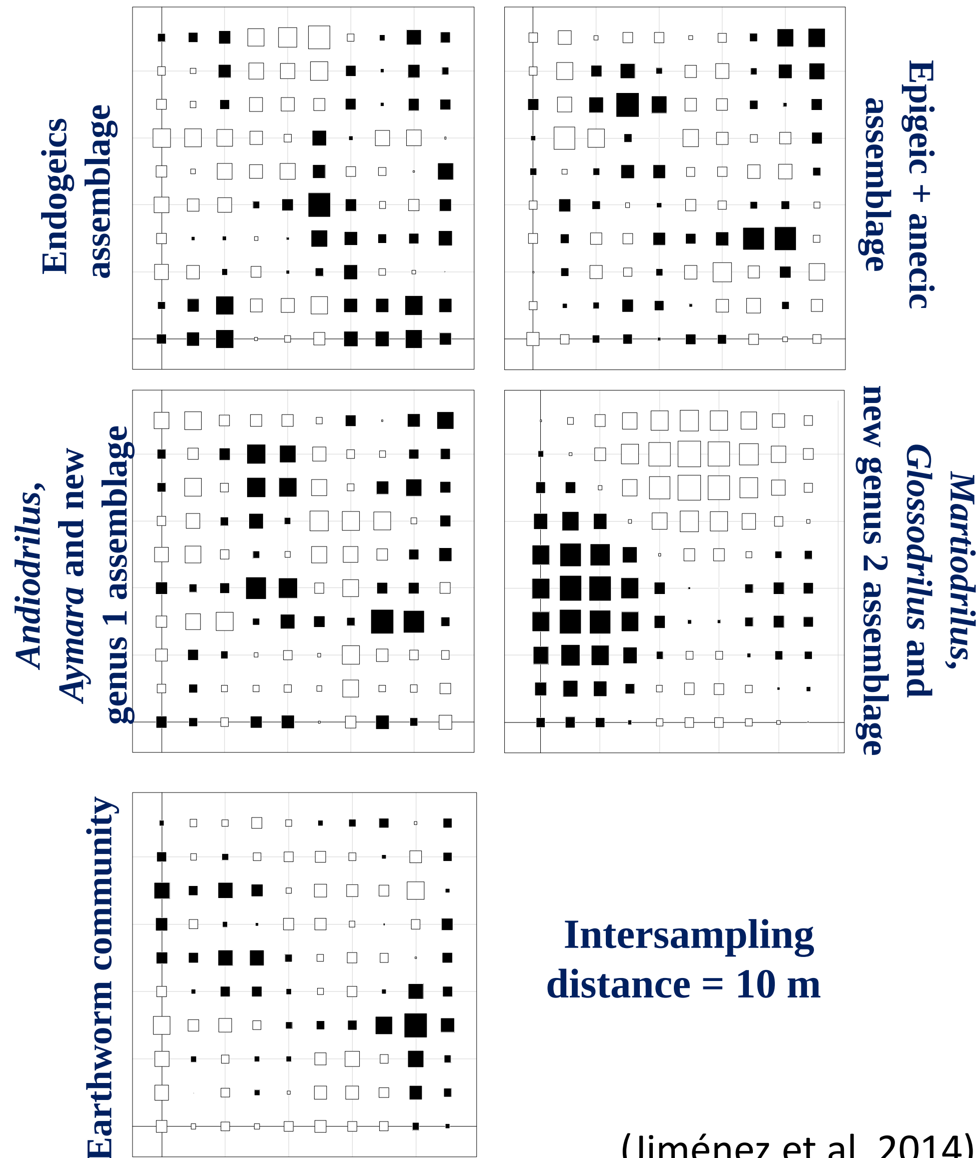
(Jiménez et al. 2011)

Variation partitioning in a spatial context

Multi-scale spatial relationships



Principal Component of Neighbouring Matrices (Dray et al. 2006) and Variation partitioning (Borcard et al. 1992; Peres-Neto et al. 2006)



Intersampling distance = 10 m

(Jiménez et al. 2014)

Environmental contribution to observed spatial pattern

Species and assemblages	Number of PCNM eigenvectors	Scales			Variation partitioning, R_a^2				Residual unexplained
		Medium (>30 m)	Fine (10-20 m)	Very fine (<10 m)	Environment	Medium scale	Fine, very fine scale	Pure spatial	
Community	6	3, 5, 8	12	33, 51	0.330 **	0.031 NS	0.01 NS	0.018	0.581
Andiodrilus	1	-	24	-	0.129 **	0.041 *	-	0.041	0.777
Aymara	9	1, 2, 5	15, 20, 24	30, 44, 47	0.002 NS	0.154 **	0.134 **	0.288	0.623
Glossodrilus	3	-	13, 24	50	0.053 *	0.081 **	0.056 **	0.141	0.785
Martiodrilus	2	5	-	56	0.032 *	0.038 *	0.048 *	0.096	0.867
New genus 1	7	3, 8	12,16	29, 33, 51	0.480 *	0.020 *	0.022 *	0.042	0.369
New genus 2	3	-	-	29, 33, 49	0.176 **	-	0.012 NS	0.013	0.812
Endogeics	4	1, 10	21	65	0.153 **	-	0.015 NS	0.016	0.816
Epigeics + anecic	7	8, 11, 15	20, 33	47, 51	0.145 **	0.098 **	0.118 **	0.235	0.639
Andiodrilus, *Aymara* and new genus 1	6	8, 11	20, 33	56, 63	0.198 **	0.123 **	0.077 **	0.222	0.526
Martiodrilus, *Glossodrilus* and new genus 2	2	2, 5			0.101 **	0.058 *	-	0.058	0.762

* $p < 0.05$; ** $p < 0.01$; NS, not significant.

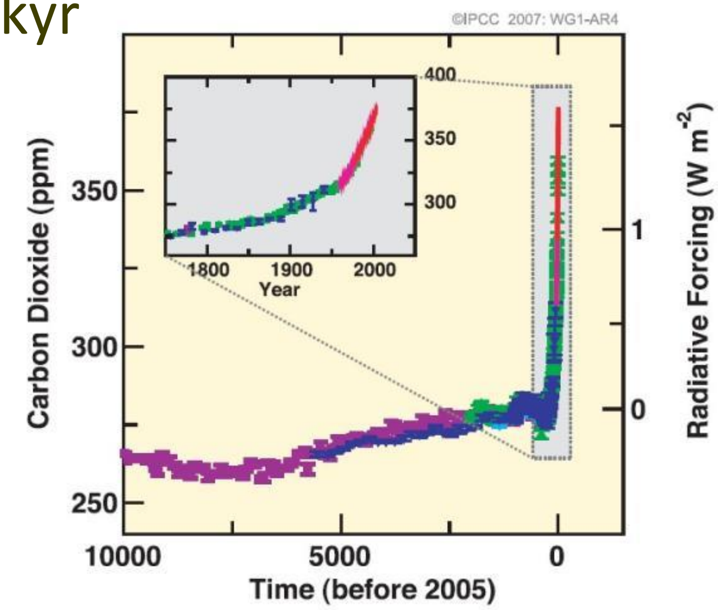
(Jiménez et al. 2014)

CLIMATE CHANGE – WHAT IS PREDICTED?

Intergovernmental Panel on Climate Change (IPCC 2007)

4th Assessment Report

- Elevated atmospheric CO_2 (eCO_2)
  - From 390 ppm in Jan 2011 to over 550 ppm by 2050
  - Antarctic ice cores show that current levels are unprecedented over the past 650 kyr
- Increased temperatures, especially over land and at most high northern latitudes (1.8 – 4 ˚C)
- The planet has already warmed up by *c.* 0.75 ˚C in the 20th century



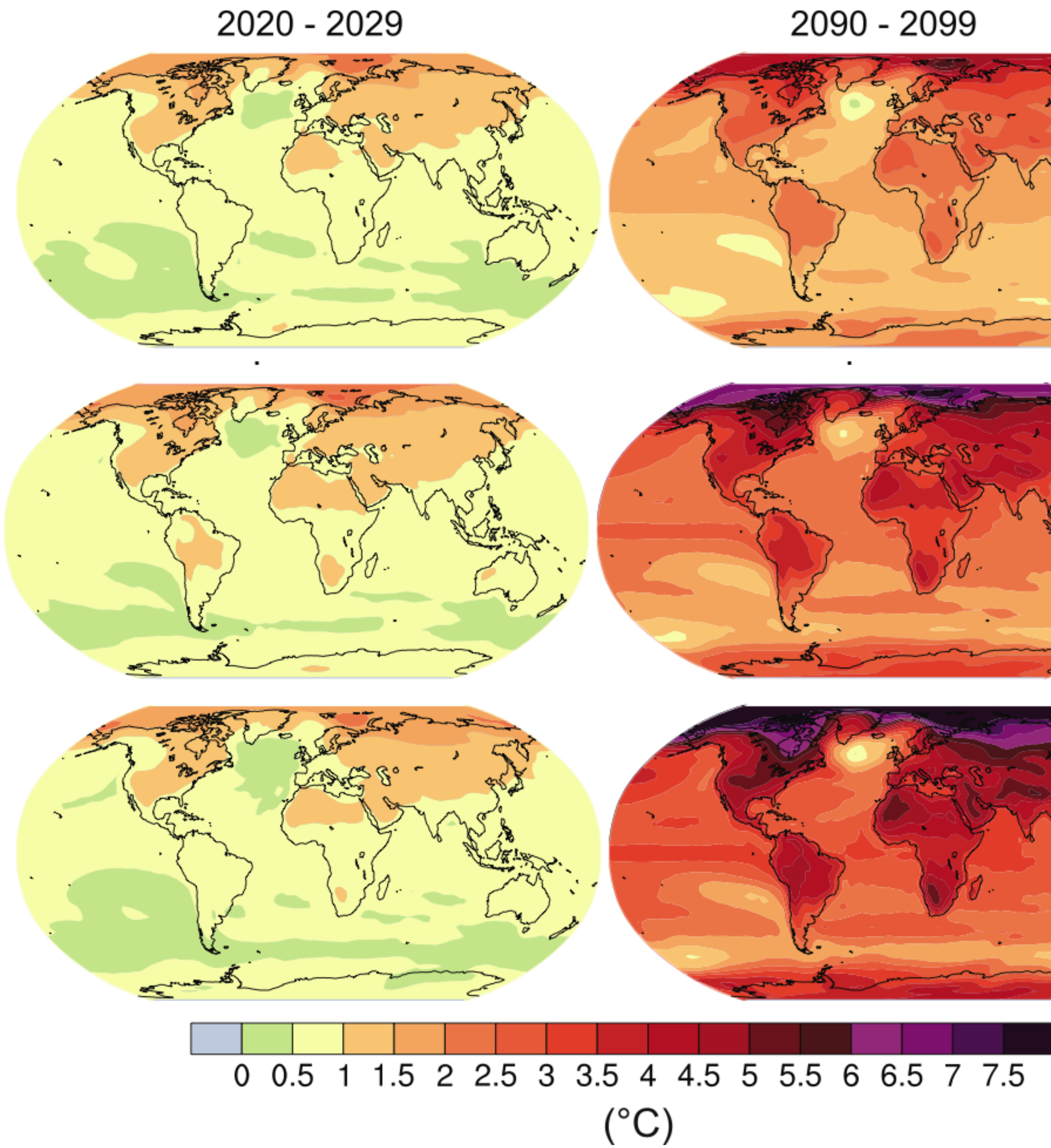
(IPCC 2007)

FUTURE TEMPERATURES : 30 & 100 YEARS

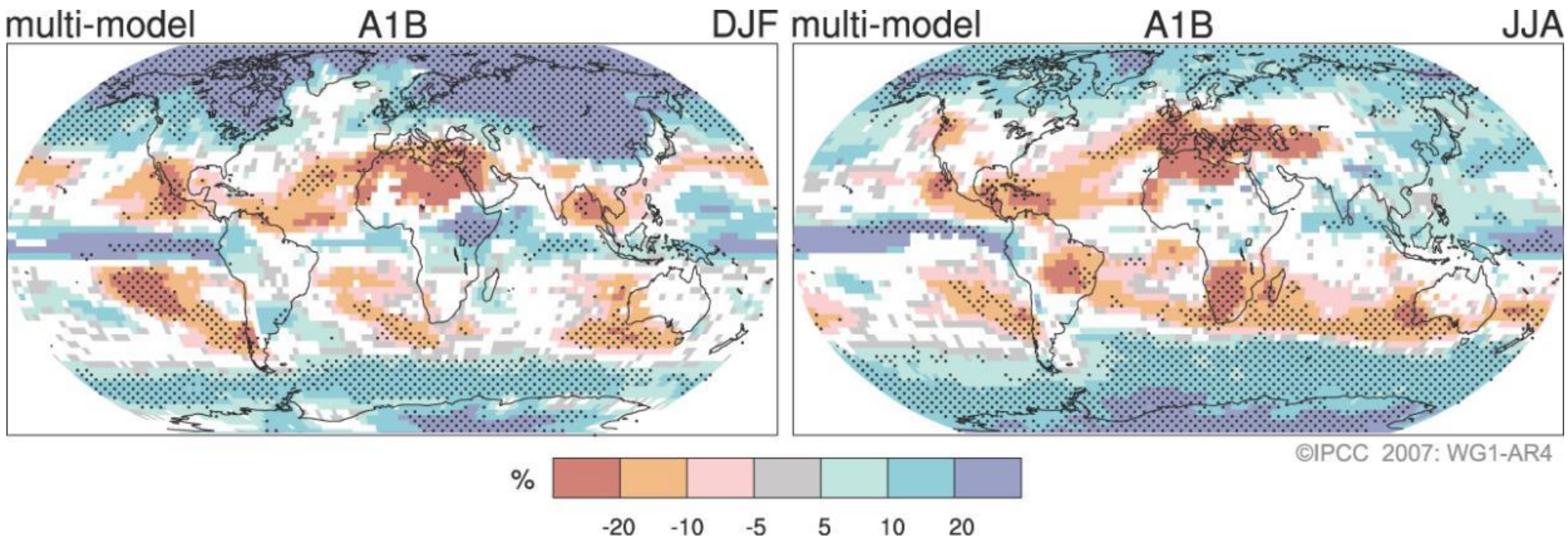
B1
global environmental sustainability

A1B
rapid economic growth (balanced emphasis on all energy sources)

A2
regionally oriented economic development (a more divided world)



FUTURE RAINFALL: 2090-99 RELATIVE TO 1980-99



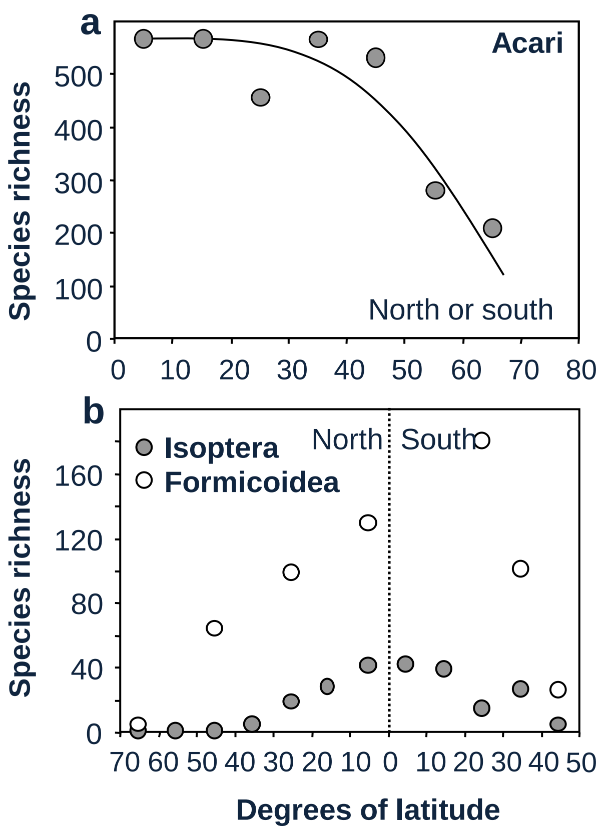
Increased rainfall in high latitudes and east Africa

Decreased rainfall in most subtropical regions

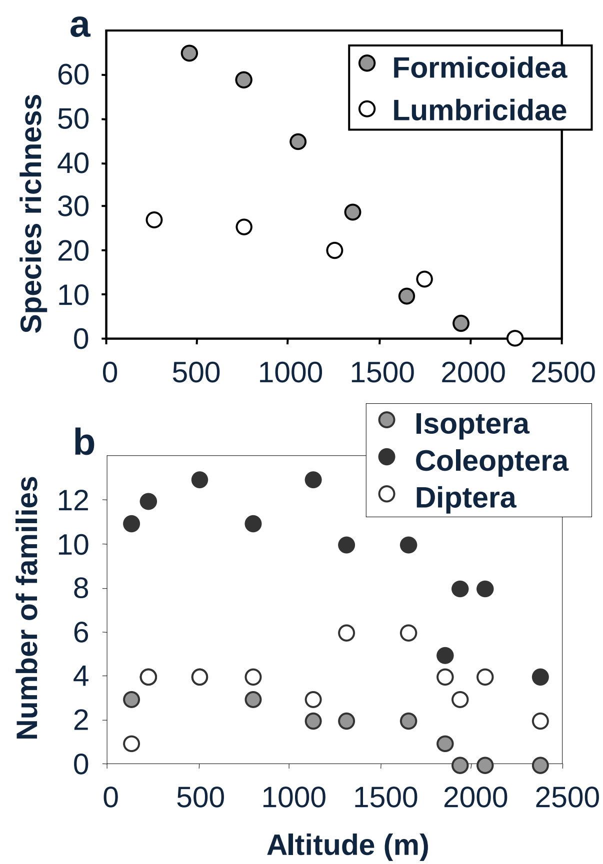
Increased rainfall during rainy seasons in the tropics

Abundance gradients

General rule: Increased species richness towards the equator for terrestrial ecosystems and increased diversity towards the pole in marine ecosystems



Latitudinal gradients of species richness for (a) oribatid mites (after Maraun et al., 2007) and (b) termites (after Lavelle & Spain, 2001) and ants (after Lavelle & Spain, 2001; Kusnezov, 1957).



Altitudinal gradients of (a) species richness of ants communities in the Smoky Mountains (after Kusnezov, 1957) and French earthworms (after Dahmouche, 2007; Bouché, 1972), and (b) taxonomic richness of several macro-invertebrate groups in Sarawak mountains (after Collins, 1980).

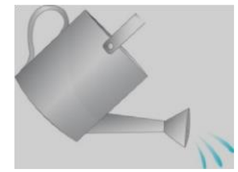
2015 Año Internacional de los Suelos

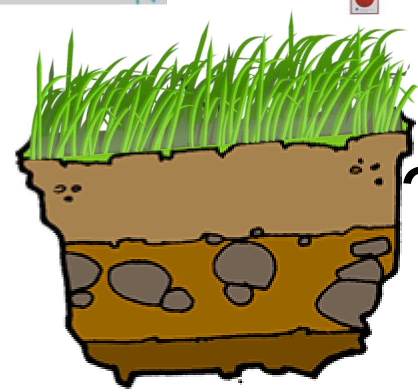
CSIC Consejo Superior de Investigaciones Científicas

IPE CSIC

Combined effects of climate change related factors on soil organisms (bacteria) – CTP Project

N addition + Temp increase





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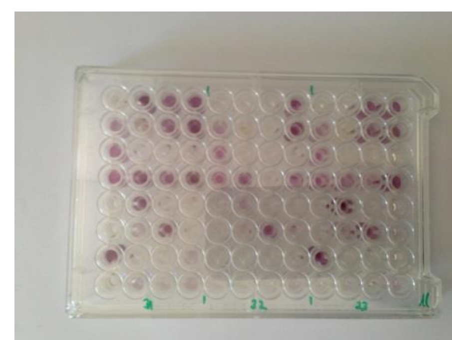

Ecoplacas Biolog™

Facts on soil organisms in response to climate change

- Important role in C cycling; they control the C sequestration process and influence greenhouse gas emissions; COST Action 2015-2019.
- Few studies to date so lack of generalizations, but single and combined effects are expected; responses context dependent.
- Soil living species (relatively constant temperatures) are less sensitive to changes in T than above-ground species, which live under more fluctuating T regimes
- Changes in geographical distribution of most invertebrates; even to remain in areas to which they are well adapted.
- Biotic responses include persistence *in situ*, range shifts to more tolerable climes or, failing these, extinction;
- Likely increase in the abundance and diversity of invertebrate pests;

Soil organisms will have to adapt, move or extinct

Cock, M.J.W., Biesmajer, J.C., Canon, R.J.C., Gerard, P.J., Gillespie, D., Jiménez, J.J., Lavelle, P., Raina, S.K. 2015. “Invertebrate genetic resources for food and agriculture and climate change”. In: FAO (Ed.) Coping with climate change. Rome.